

BL1500

C-Programmable Controller

User's Manual

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BL1500 User's Manual

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ABOUT THIS MANUAL

This manual provides instructions for installing, testing, configuring, and interconnecting any of the Dynamic C programmable controllers in the BL1500 series.

The term “BL1500” will be used generically throughout this manual when referring to any controller in the BL1500 series. Where information applies to a specific controller, the model number will be specified. Models currently covered by this manual include the BL1500, BL1510, and BL1520.

Instructions to get started using Dynamic C software programming functions as well as complete C and Dynamic C references and programming resources are referenced when necessary.

Assumptions

Assumptions are made regarding the user's knowledge and experience in the following areas:

- Ability to design and engineer a target system that a BL1500 will control.
- Understanding of the basics of operating a software program and editing files under Windows on a PC.
- Knowledge of the basics of C programming.



For a full treatment of C, refer to the following texts:
The C Programming Language by Kernighan and Ritchie
C: A Reference Manual by Harbison and Steel

- Knowledge of basic Z80 assembly language and architecture.



For documentation from Zilog, refer to the following texts:
Z180 MPU User's Manual
Z180 Serial Communication Controllers
Z80 Microprocessor Family User's Manual

Acronyms

Table 1 lists and defines the acronyms that may be used in this manual.







Table 1. Acronyms

Acronym	Meaning
EPROM	Erasable Programmable Read-Only Memory
EEPROM	Electrically Erasable Programmable Read-Only Memory
LCD	Liquid Crystal Display
LED	Light-Emitting Diode
NMI	Nonmaskable Interrupt
PIO	Parallel Input/Output Circuit (Individually Programmable Input/Output)
PRT	Programmable Reload Timer
RAM	Random Access Memory
RTC	Real-Time Clock
SIB	Serial Interface Board
SRAM	Static Random Access Memory
UART	Universal Asynchronous Receiver Transmitter

Icons

Table 2 displays and defines icons that may be used in this manual.

Table 2. Icons

Icon	Meaning	Icon	Meaning
	Refer to or see		Note
	Please contact	Tip	Tip
	Caution		High Voltage
	Factory Default		

Conventions

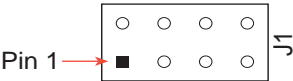
Table 3 lists and defines the typographic conventions that may be used in this manual.

Table 3. Typographic Conventions

Example	Description
while	Courier font (bold) indicates a program, a fragment of a program, or a Dynamic C keyword or phrase.
// IN-01...	Program comments are written in Courier font, plain face.
<i>Italics</i>	Indicates that something should be typed instead of the italicized words (e.g., in place of <i>filename</i> , type a file's name).
Edit	Sans serif font (bold) signifies a menu or menu selection.
...	An ellipsis indicates that (1) irrelevant program text is omitted for brevity or that (2) preceding program text may be repeated indefinitely.
[]	Brackets in a C function's definition or program segment indicate that the enclosed directive is optional.
< >	Angle brackets occasionally enclose classes of terms.
a b c	A vertical bar indicates that a choice should be made from among the items listed.

Pin Number 1

A black square indicates pin 1 of all headers.



Measurements

All diagram and graphic measurements are in inches followed by millimeters enclosed in parenthesis.



*CHAPTER 1: **OVERVIEW***

Chapter 1 provides an overview and brief description of the BL1500 features, options, and optional upgrades.

Overview

Each BL1500 controller is a small, low-cost board that is easily programmed using Dynamic C. Moreover, each controller offers impressive processing power for a wide variety of control applications. Despite its small size, a BL1500 can accommodate large, real-time multitasking programs.

Real-time programs can be developed on any of the BL1500 controllers in the target system without the need for expensive in-circuit emulators or logic analyzers.

All BL1500s allow for protecting data in static RAM and the real-time clock's contents with an external backup battery (2.5 V to 4.25 V DC).

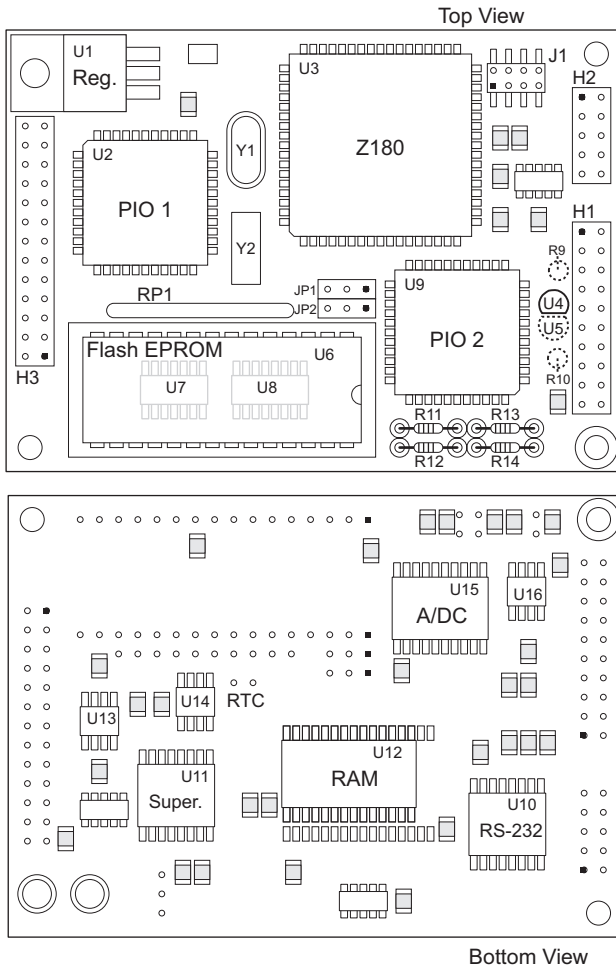


Figure 1-1. BL1500 Board Layout

Features

BL1500

- Two Zilog PIO ICs for parallel or bit-oriented digital I/O, 26 total digital I/O lines plus handshake lines
- Socket for up to 256K flash EPROM
- Power supervisor IC consisting of watchdog timer, power-fail reset, and RAM backup-battery switchover
- Linear voltage regulator (5 V)
- RS-232 serial channel
- RS-485 serial channel
- Serial Interface Board 2 programming port
- Connection for external backup battery (2.5 V to 4.25 V DC) on pin 21 of header H3
- Keypad and LCD interface
- A real-time clock (RTC), which provides time and date functions and a 31-byte scratchpad RAM. The RTC reserves two digital-I/O lines, leaving 24 I/O lines for an application's use.
- SRAM (128K)
- Four-channel, 12-bit A/D converter. Two channels have onboard, user-defined signal conditioning, and the other two are unconditioned.

BL1510

- All features of the BL1500 except RTC
- Two additional PIO lines
- SRAM (32K)

BL1520

- All features of the BL1500 except RTC and 12-bit A/D converter.
- Two additional PIO lines
- SRAM (32K)



Appendix B, "Specifications," provides a complete list and description of BL1500 specifications.

Options and Upgrades

- Serial Interface Board 2 (SIB2) allows programming through the special programming port, leaving both serial channels available for applications.
- 128K or 256K flash EPROM can be factory installed.
- 128K EPROM.
- Real-time clock provides time and date functions and a 31-byte scratchpad RAM. The RTC reserves two digital-I/O lines, leaving 24 I/O lines for use by the application. This feature is standard on the BL1500, but can be added to the BL1510 and BL1520 models.

Software Development and Evaluation Tools

Software for the BL1500 is developed using Dynamic C, Z-World's real-time C language development system. Dynamic C for the BL1500 runs under Windows on a PC.

When a program compiles, the host PC downloads the executable code, via the BL1500's RS-232 port, directly to the onboard flash EPROM. This feature allows fast in-target development and debugging.

Another method for downloading programs from a host PC to a BL1500 is via a Z-World Serial Interface Board 2. By using the optional SIB2, the RS-232 port is left free for other applications.

The BL1500 supports up to 256K of electronically re-programmable flash EPROM. Flash EPROM allows programs to be downloaded into nonvolatile memory without using an EPROM burner.



Z-World's Dynamic C reference manuals provide complete software function descriptions and programming instructions.



*CHAPTER 2: **GETTING STARTED***

Chapter 2 provides instructions for connecting the BL1500 to a host PC and running a sample program. Sections include the following topics:

- Developer's Kit Packing List
- Connecting the Prototyping Board to the BL1500
- Connecting the BL1500 to a Host PC
- Establishing Communication
- Running a Sample Program

Developer's Kit Packing List

The Developer's Kit includes items necessary for BL1500 software and hardware development. The kit includes the following items.

- An aluminum base plate/heat sink that allows the BL1500's voltage regulator to dissipate up to 3.5 W at 50°C.
- Prototyping Board for prototyping BL1500 expansion circuits, and powering the BL1500 during development. The Prototyping Board measures 2.25×2.0 inches and connects directly to the BL1500. The board includes several sample circuits, a power jack, and a small prototyping area where circuits can be soldered for special needs.
- A 128K flash EPROM.
- Wall power supply (12 V DC).
- Programming serial cable.
- Miscellaneous small hardware parts such as assorted connectors, screws, and standoffs. Also, 26-pin cable connector and 20 crimp pins that may be used to construct a cable to meet specific needs.
- A reference manual with schematics.

Installing Flash EPROM

If an EPROM is not already installed, install the flash EPROM from the Developer's Kit in socket U6 on the BL1500 shown in Figure 2-1. Make sure the jumpers on headers JP1 and JP2 are set as shown in Figure 2-1.

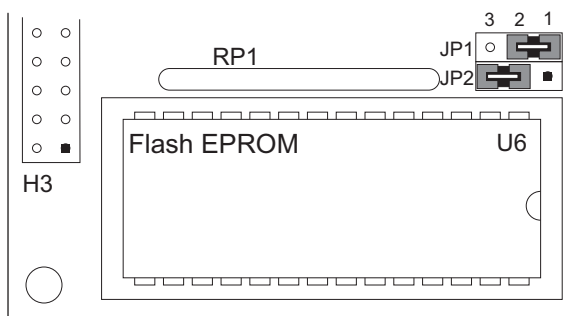


Figure 2-1. Flash EPROM Installation and Jumper Settings

Connecting the Prototyping Board to the BL1500

The Prototyping Board connects to the top of the BL1500. The 26-pin header (H3) on the BL1500 plugs into the socket strip (H1) on the underside of the Prototyping Board. Most of the Prototyping Board extends beyond the edge of the BL1500. Figure 2-2 illustrates how to attach the Prototyping Board to the BL1500.

Pin 1 of header H1 on the Prototyping Board must match pin 1 of header H3 on the BL1500.

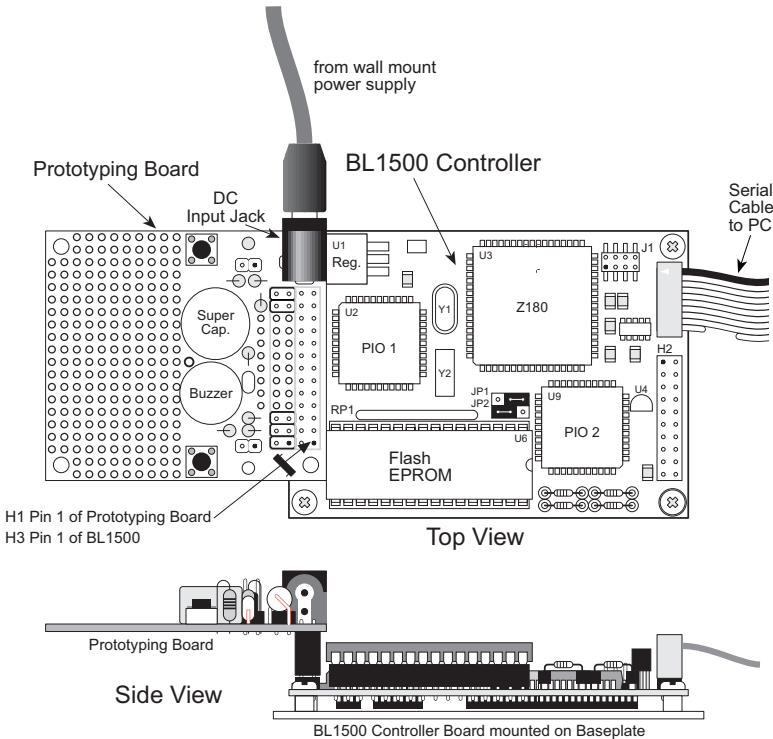


Figure 2-2. Prototyping Board Attachment to BL1500



The Prototyping Board does not require jumpers on its header H2. Remove the jumpers that are shipped with the Prototyping Board.

The Prototyping Board supplies power to the BL1500. Plug the power supply into the wall and connect it to the direct current input jack on the Prototyping Board. The BL1500 is now ready for programming.



Refer to Appendix D, “Prototyping Board,” for a full description and additional information.

When using the Prototyping Board during software development, power (9 V to 12 V DC) comes through the direct current input jack of the Prototyping Board. In the absence of this board (for example, when you have completed system development), apply power to pin 25 of header H3.



Always connect the Prototyping Board as shown in Figure 2-2. Joining the board any other way could damage the BL1500's components.

Connecting the BL1500 to a Host PC

The BL1500 can be connected to a host PC via the RS-232 port or via a SIB2. Although the ideal development method is with a SIB2, the RS-232 port is the BL1500's onboard development serial port. When a SIB2 is used, the RS-232 port is available during development to compile and debug a program.

BL1500 connectors are not polarized or keyed. Carefully observe connector orientation and pin alignment before making a connection and before applying power.



All diagrams in this manual illustrate pin 1 of each connector as a solid black square.

Development Using the RS-232 Port

Using the programming cable provided in the Developer's Kit, connect the BL1500 to a host PC with the following steps. Figure 2-3 illustrates the connection between the BL1500 and the host PC.

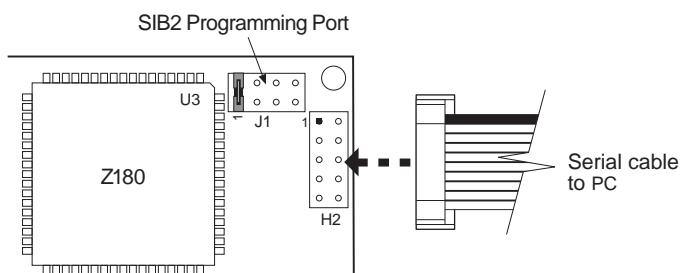


Figure 2-3. RS-232 Programming Mode

1. Disconnect power source to the BL1500.
2. Connect the RS-232 cable between the host PC's COM port and header H2 of the BL1500. Be careful to match the arrow on the connector to pin 1 of header H2.
3. Connect a jumper between pins 1 and 2 of header J1 (the SIB2 port).
4. Reconnect power source.

The BL1500 is now ready for programming through the RS-232 port.

Developing with Optional SIB2

Z-World's SIB2 is an interface adapter useful for BL1500 software development. Contained in an ABS plastic enclosure, the SIB2 is rugged and reliable. Since the SIB2 permits the BL1500 to communicate with Dynamic C via the Z180's rarely used clocked serial I/O (CSI/O) port, the BL1500's serial port is freed up. The serial port can then be used by an application.

The SIB automatically selects its RS-232 baud rate to match certain communication rates established by the host PC through Dynamic C. However, the host's communication baud rate is determined only on the first communication after reset. To change baud rates, first change the baud rate through the Dynamic C **Serial** option in the **OPTIONS** menu, then reset the target BL1500 (also resets the SIB2), then select **Reset Target** or **<Ctrl Y>** in Dynamic C. The SIB2 automatically matches the baud rate of the host PC at 9600 bps, 19,200 bps, or 57,600 bps.

Follow these steps to connect a SIB to a host PC.

1. Disconnect power to the BL1500 if connected.
2. Connect the 6-conductor RJ-12 cable from the PC's COM port to the SIB2.
3. Connect the SIB2's small ribbon cable to header J1 on the BL1500 as shown in Figure 2-4. Match the arrow on the SIB2 connector to pin 1 of header J1.

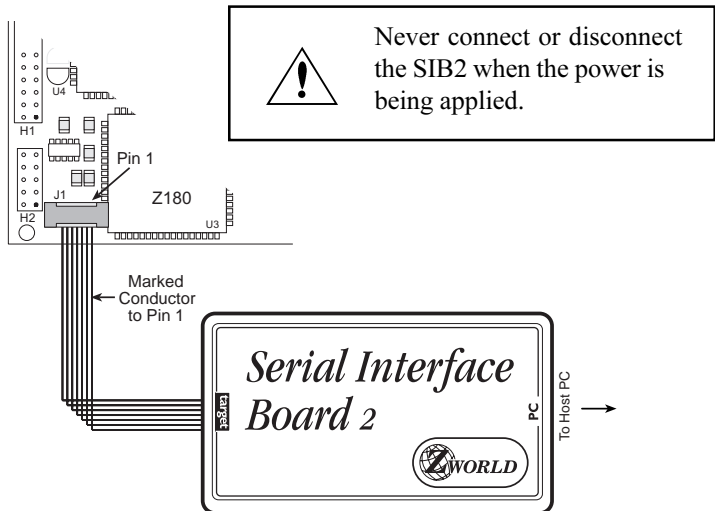


Figure 2-4. Serial Interface Board 2 Connection to BL1500

4. Reconnect the power supply to the BL1500.

The system is now ready for programming through the SIB2.

Establishing Communication

After hardware is connected, communication can be established between a host PC and the BL1500.

Communication is established by double-clicking the Dynamic C icon to start the software.



Communication with the BL1500 is attempted each time Dynamic C starts.

When communication is established, no error messages are displayed.



See Appendix A, “Troubleshooting,” if an error message such as **Target Not Responding** or **Communication Error** appears.

After making any necessary changes to establish communication between the host PC and the BL1500, use the Dynamic C shortcut **<Ctrl Y>** to reset the controller and initialize communication.

Running a Sample Program

The following steps describe how to run a sample program to determine if hardware connections are correctly established.

1. Open the sample program **MGDEMORT.C** located in the Dynamic C **SAMPLES\BL14_15** subdirectory.
2. Compile the program by pressing **<F3>** or by choosing **Compile** from the **COMPILE** menu. Dynamic C compiles and downloads the program into the BL1500’s flash memory.

During compilation, Dynamic C rapidly displays several messages in the compiling window. This condition is normal.

3. To run the program, press **<F9>**, or choose **Run** from the **RUN** menu.
5. To halt the program execution, press **<Ctrl Z>**.
6. To restart program execution, press **<F9>**.



CHAPTER 3: **SUBSYSTEMS**

Chapter 3 discusses the following topics.

- Interface Overview
- PIOs (Programmable I/O ICs)
- Power-Supervisor Integrated Circuit
- Serial Communication Ports
- Analog-to-Digital Converter
- Real-Time Clock

Interface Overview

This section describes the various interfaces of the BL1500. Figure 3-1 provides a block diagram reference of the available interfaces.

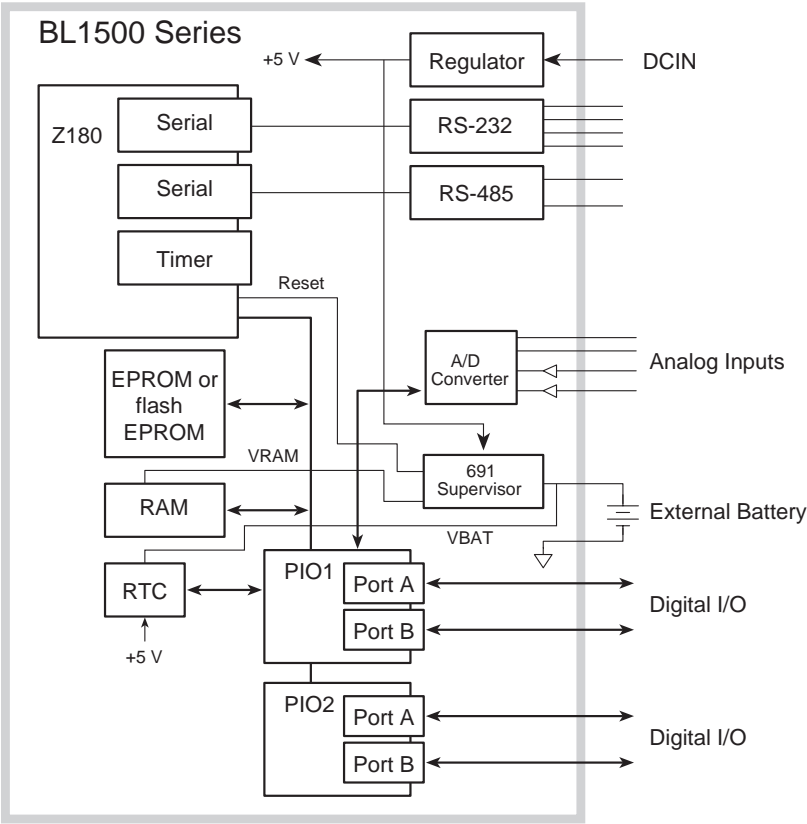


Figure 3-1. BL1500 Interface Diagram

Programmable Input/Output ICs (PIOs)

The BL1500 uses two Zilog PIO ICs to provide digital I/O signals: (1) PIO 1, U2, (2) and PIO 2, U9.

Each PIO has two 8-bit, parallel, programmable I/O ports called “Port A” and “Port B.” Each line of a port can serve as an input or output in different modes.

The signal nomenclature identifies the various ports and pins of the PIOs discussed in this section.

- P1A0–P1A7 are data lines 0 through 7 of PIO 1 Port A.
- P2B7 is data line 7 of PIO 2 Port B.



Drivers for PIO 1 **do not** indicate a PIO number.
Drivers for PIO 2 **do** indicate a PIO number.

PIO Modes of Operation

There are four modes of operation for PIO Port A and Port B. Port A of PIO 1 may operate in modes 0, 1, and 3, but not in mode 2. Port A of PIO 2 operates in mode 3, bitwise I/O only. Likewise, both PIOs of Port B operate in mode 3, bitwise I/O only. Table 3-1 and Table 3-2 list and define the four modes of operation.

Table 3-1. PIO Modes of Operation

Mode	Description
Mode 0	Strobed byte output
Mode 1	Strobed byte input
Mode 2	Bidirectional data transfer
Mode 3	Bitwise I/O, input/output selectable per bit

Table 3-2. Permissible PIO Port Operating Modes

Mode	PIO 1		PIO 2	
	Port A	Port B	Port A	Port B
Mode 0	Yes	No	No	No
Mode 1	Yes	No	No	No
Mode 2	No	No	No	No
Mode 3	Yes	Yes	Yes	Yes

The PIO lines can also detect transitions interrupting the microprocessor in various ways. Although each port has two handshake lines, the only usable handshake lines for Port A of PIO 1 appear on header H3.

Port A lines have TTL-compatible logic levels. In addition to being TTL-compatible, Port B lines can supply up to 1.5 mA at 1.5 V to drive Darlington transistors. For either port, you may need to add current-limiting resistors, noise filters, or transient voltage suppression circuitry, depending on the application.

The impedance of a PIO line is approximately 80 Ω for sinking current and 160 Ω for sourcing current. Do not apply negative voltages (voltages below ground) or voltages above VCC (+5 V) to either PIO.

PIO 1

Four lines of PIO 1 Port B are preassigned. Figure 3-2 illustrates each line location and Table 3-3 lists and defines the signals and their function for specific pins.

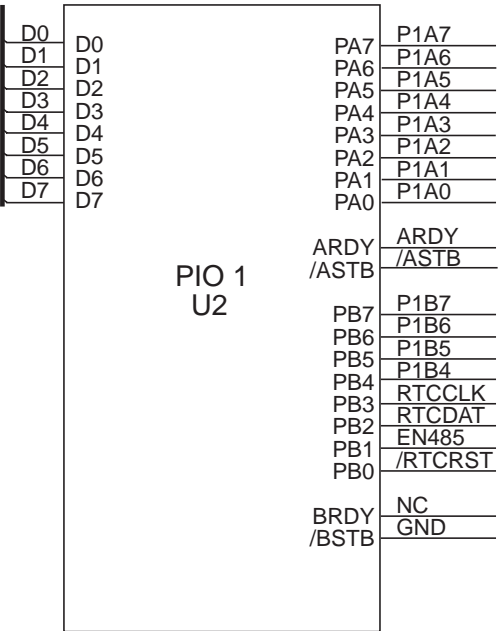


Figure 3-2. PIO 1 Line Map

Table 3-3. PIO 1 Preassigned Pins

PIO 1 Port	Pin Signal	Pin Function
P1B3	RTCCLK	RTC serial clock
P1B2	RTCDAT	RTC serial data
P1B1	EN485	RS-485 transmit enable
P1B0	/RTCRST	RTC reset

H3 Signals

Header H3 brings out the usable I/O lines of PIO 1 plus several other miscellaneous signals. Table 3-4 lists and defines the usable I/O lines and other signals for header H3.

Table 3-4. PIO 1 Signals on Header H3

H3 Pin	Signal	Signal Description
1	+5 V	Regulated Power
2	P1A0	PIO 1 Port A, Data Line 0
3	P1A1	PIO 1 Port A, Data Line 1
4	P1A2	PIO 1 Port A, Data Line 2
5	P1A3	PIO 1 Port A, Data Line 3
6	P1A4	PIO 1 Port A, Data Line 4
7	P1A5	PIO 1 Port A, Data Line 5
8	P1A6	PIO 1 Port A, Data Line 6
9	P1A7	PIO 1 Port A, Data Line 7
10	GROUND	Digital Ground
11	ARDY	PIO 1 Port A Handshake Line
12	/ASTB	PIO 1 Port A Handshake Line
13	P1B7	PIO 1 Port B, Data Line 7
14	P1B6	PIO 1 Port B, Data Line 6
15	P1B5	PIO 1 Port B, Data Line 5
16	P1B4	PIO 1 Port B, Data Line 4
17	RTCCLK	Real-Time Clock Control Lines
18	RTCDAT	Real-Time Clock Data Line
19	/RESET	Reset Signal
20	GROUND	Digital Ground
21	VBAT	External Battery Input
22	GROUND	Digital Ground
23	RS-485+	RS-485+
24	RS-485-	RS-485-
25	DCIN	Unregulated Voltage Input
26	GROUND	Digital Input



Since the BL1510 and BL1520 do not have a real-time clock (RTC), PIO 2 lines P1B3 and P1B2 are available for use.

PIO 2

Eight data lines from Port A and four lines from Port B are available for general-purpose I/O functions. The remaining four lines of Port B have been preassigned to the BL1500's A/D converter. If an A/D converter is not installed, the four remaining lines are available for other functions. Figure 3-3 illustrates each line location and Table 3-5 lists and defines the signals and their function for specific pins.

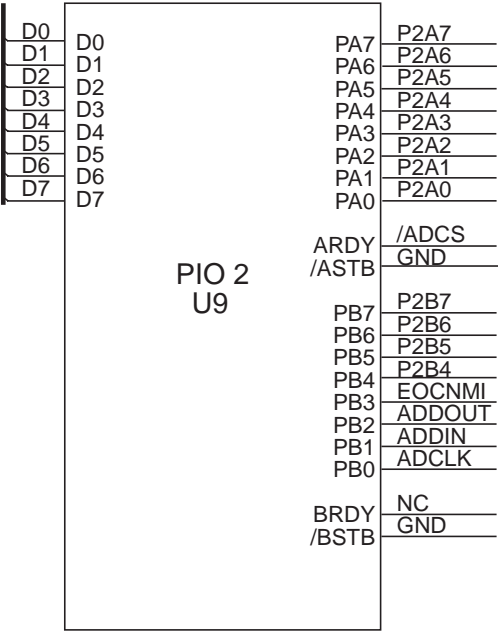


Figure 3-3. PIO 2 Line Map

Table 3-5. PIO 2 Preassigned Analog-to-Digital Lines

PIO 2 Port	Signal	Analog-to-Digital Function
P2B3	EOCNMI	End of Conversion and Power Fail Sense
P2B2	ADDOUT	Output Data
P2B1	ADDIN	Input Data and Commands
P2B0	ADCLK	Clock

H1 Signals

Header H1 brings out the usable I/O lines of PIO 2 plus the A/D converter signals. Table 3-6 lists and defines the usable I/O lines and other signals for H1.

Table 3-6. PIO 2 Signals on Header H1

H1 Pin	Signal	Signal Description
1	+5 V	Regulated Power
2	P2A0	PIO 2 Port A, Data Line 0
3	P2A1	PIO 2 Port A, Data Line 1
4	P2A2	PIO 2 Port A, Data Line 2
5	P2A3	PIO 2 Port A, Data Line 3
6	P2A4	PIO 2 Port A, Data Line 4
7	P2A5	PIO 2 Port A, Data Line 5
8	P2A6	PIO 2 Port A, Data Line 6
9	P2A7	PIO 2 Port A, Data Line 7
10	GROUND	Digital Ground
11	P2B4	PIO 2 Port A, Data Line 4
12	P2B5	PIO 2 Port A, Data Line 5
13	P2B6	PIO 2 Port A, Data Line 6
14	P2B7	PIO 2 Port A, Data Line 7
15	AD2	Unconditioned A/D Input
16	AD3	Unconditioned A/D Input
17	VREF	A/D Voltage Reference
18	AD1	Conditioned A/D Input
19	AGND	Analog Ground
20	AD0	Conditioned A/D Input



Pins are provided for both analog and digital ground. Make it standard practice to observe the following conventions.

- Do not mix analog and digital ground signals.
- Do not connect analog ground to digital ground external to the BL1500.
- Return sensitive, low-level analog signals to analog ground.
- Return high current, on-off signals to digital ground.

Power-Supervisor Integrated Circuit

The ADM691 power-supervisor IC is a key component that helps a system survive power fluctuations and power outages. Several vital services provided by the power supervisor are described below.

- **Power-on reset**

The supervisor IC generates the power-on reset for the BL1500 by holding /RESET low until the IC senses that VCC has risen above the reset threshold (~4.65 V) and the battery voltage (2.5 V to 4.25 V DC). When VCC falls below the threshold, the supervisor IC disables the RAM to prevent spurious writing of data.

- **RAM protection**

The power supervisor IC gates the decoded RAM-select line (/RAMSEL) to the RAM's chip-enable line (/RAMCE) whenever VCC is above the reset threshold and VBAT. When VCC falls below the threshold, the ADM691 de-asserts /RAMCE to prevent spurious writing to the RAM.

- **Watchdog timer**

The watchdog timer cannot be disabled. The watchdog timer guards against system or software faults. If an application does not “hit” the watchdog timer at least every 1.0 seconds, the watchdog timer resets the Z180. The supervisor's watchdog output (/WDO) connects to the Z180's /INT1 interrupt line. /WDO is at logic zero level after a watchdog reset and at logic 1 after a power-on reset.



To “hit” the watchdog timer, make a call to the library function **hitwd**. This call makes a dummy one-byte DMA transfer via DMA channel 1, which activates the DMA-end signal, /TEND1, “hitting” the watchdog timer.

- **Nonmaskable interrupt**

The ADM691 generates a nonmaskable interrupt (/NMI) from its power-fail output (/PFO) for the microprocessor if the unregulated DC input (normally 9 V to 12 V DC) falls below 7.9 V. This gives the BL1500 advanced warning of an impending power failure, which allows it to execute shutdown routines. The voltage divider (R1 and R15) determines the power-fail voltage level.

R16 introduces approximately 830 mV of hysteresis into the supervisor IC's sensing of the raw DC, preventing noise on DCIN from generating repeated interrupts when the input voltage is low. /NMI also connects to Port B (bit 3) of PIO 2 (via U7B) to allow your software to monitor the /NMI line after the nonmaskable interrupt, and to recover from temporary low-input voltage conditions or “brownouts.”

- **Backup-battery switchover**

The ADM691 switches the RAM over to battery power if VCC falls below the battery voltage VBAT (2.5 V to 4.25 V DC).



Provide an external backup battery to take advantage of the backup battery switchover. Resistor R17 prevents false resets when changing the battery with the power on.

Serial Communication Ports

Two Z180 serial ports support asynchronous communication at baud rates from 300 bps to 57,600 bps.

- 1. Port 0 is a 5-wire RS-232 port (with RTS and CTS).
- 2. Port 1 is a half-duplex RS-485 port, which provides half-duplex asynchronous communication over twisted pair wires to a distance of up to 4 kilometers.

Figure 3-4 illustrates the configuration of Port 0 and Port 1.

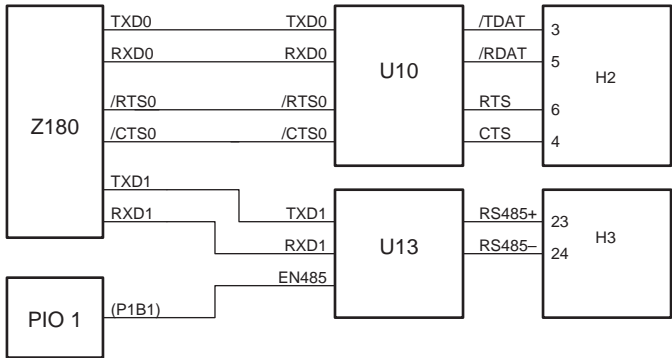




Figure 3-4. Serial Communication Port Configuration

RS-485

Header H3 provides a half-duplex RS-485 serial interface. RS-485 is an asynchronous multidrop half-duplex standard. The BL1500 can be configured to provide one channel of RS-485 communication with multidrop network capabilities. The RS-485 signals are on pins 23 and 24 of header H3, and also on pins 23 and 24 of header H2 on the Prototyping Board.

 Chapter 4, “System Development” describes how to configure a multidrop network.

 See Z-World’s Dynamic C reference manuals for details on master-slave networking.

RS-232 and Programming Ports

Header H2 provides a 5-wire RS-232 interface that is used for programming. However, the BL1500 can be programmed without using the RS-232 port by using the Serial Interface Board 2 (SIB2). By connecting a SIB2 to header J1, the Z180 port can be used for programming and debugging, leaving the RS-232 interface available to an application during development.

Z-World has RS-232 support libraries for the BL1500's Z180 Port 0. Support for serial communication includes the following functions.

- Initializing the serial ports.
- Monitoring and reading a private circular receive buffer.
- Monitoring and writing to a private circular transmit buffer.
- CTS (clear to send) and RTS (request to send) control.
- XMODEM protocol for downloading and uploading data.
- A modem option.
- An echo option.

Modem Communication

Modems and telephone lines allow RS-232 communication across great distances. A modem automatically scans character streams that are read from the receive buffer for modem commands. The RS-232 library supports communication with a Hayes Smart Modem or compatible modem. If the modem used is not truly compatible, you must tie the CTS, RTS, and DTR lines on the modem side together. Additionally, the CTS and RTS lines on the BL1500 side also have to be tied together. A NULL connection is also required for the TX and RX lines. However, a commercial NULL modem already has its CTS and RTS lines tied together on both sides.

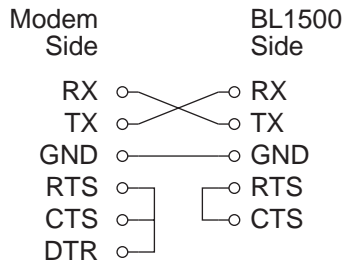


Figure 3-5. Connections Between Controller and Modem

Figure 3-5 illustrates the connections between a BL1500 and a modem.

The BL1500 supports the XMODEM protocol for downloading and uploading data. Currently, the library supports downloading an array of data in multiples of 128 bytes.

Uploaded data are written to a specified area in RAM. The targeted writing area should not conflict with the current resident program or data.

Character echo is automatically suspended during XMODEM transfer.



See Z-World's Dynamic C reference manuals for details on software functions for modem communication.

Analog-to-Digital Converter

The optional BL1500 A/D converter is a 12-bit, serial-I/O, switched-capacitor, successive-approximation converter that can monitor temperature, measure position, or sense other types of analog signals. In response to commands received from the Z180 via PIO 2, the A/D converter's internal multiplexer samples and converts one input channel at a time.

Based on the A/D converter's minimum conversion period, the maximum data conversion rate is approximately 5,000 conversions per second. Z-World cannot guarantee this level of performance because application programming can have a major affect on the conversion rate.

The A/D converter IC provides four channels of 12-bit analog-to-digital conversion. Two of the channels have op-amps for signal conditioning and two are unconditioned. The input range for the unconditioned channels is 0 V to 2.5 V. The two unconditioned channels also have onboard sensor-excitation resistors.

A dual op-amp (U16) buffers the two analog inputs received over signal lines AD0 and AD1 of header H1. The outputs of U16 go to the first two inputs of the A/D converter's (U15) eleven inputs. The two unconditioned signals AD2 and AD3 go through anti-latchup resistors R5 and R7 to the next two A/D inputs.

Extra Conversion

The A/D converter sends converted data out serially and receives commands serially. During each serial-clock cycle, the chip shifts in one command bit and shifts out one data bit. This combined shifting accounts for the device's behavior of returning a previous data reading automatically each time it accepts a conversion or configuration command.

The A/D converter communicates with the Z180 via data-input line ADDIN, the data-output line ADDOUT, the clock line ADCLK, the end-of-conversion line EOC, and the IC-select line /ADCS.

EOC goes to a logic "0" level during conversion, returning to "1" when the conversion is complete. Following the conversion period, the A/D converter shifts the resulting data one bit at a time over ADDOUT. Also, during each shift-clock period, the converter shifts in one bit of a command word into the converter over ADDIN. This command word specifies the converter's next operation. The PIO's ARDY line drives /ADCS. This line goes from a logic "1" to "0" during power-on initialization as a result of putting Port A into mode 3 operation. This transition is necessary for the chip to function properly. After transition, the line is left low.

EOC comes in over PIO Port B data line 3 (P2B3), which also senses /NMI through the logic gate U7. (/NMI and EOC are not at a logic 0 level at the same time, and the driver software can distinguish between them in context.)

Library routines take care of all the low-level details of communication with the A/D converter automatically.



The protocol for controlling the serial A/D converter is complex. Z-World strongly recommends using existing Dynamic C library functions to control the converter instead of writing your own functions.

Voltage Reference

The A/D converter's two reference inputs REF- and REF+ establish the voltage limits for analog inputs that produce the maximum and minimum conversion values. Inputs higher than REF+ return the maximum conversion value, and inputs less than REF- return the minimum conversion value. The A/D converter has no out-of-range signal. Software will not be able to distinguish between an input that is exactly at either limit of the voltage range and an input that exceeds the limits.

Data Conversion

The two conditioned inputs measure input signals over either a bipolar or a unipolar voltage range. In either case, the operational amplifier's gain and bias resistors scale the signal ranges to conform to the 0 V to 2.5 V input range of the A/D converter. The inverting configuration of the op-amps means that the maximum input voltage results in a minimum input voltage at the converter.

The A/D converter determines a 12-bit digital value representing the converted value of the input voltage. An input voltage at the A/D converter (equal to 0 V) converts to all zeros, and an input at 2.5 V converts to all ones. Dynamic C functions return 16-bit sign-extended values. The functions return a reading appropriate to the unipolar or bipolar signals being measured, based on the arguments supplied to the function.

Limitations on Output Range

In actual practice, the op-amp outputs can only approach ground (0 V) but cannot actually reach it. The output low-voltage limit is about 10 mV to 20 mV. The practical effect of this limitation is that approximately 0.4%–0.8% of the upper end of the input-signal range is unusable. For example, if the input signal ranges from 0 V to 10 V, the maximum useful input voltage is 9.92 V to 9.96 V.

Low-Pass Filter

The 0.01 μF feedback capacitors (C20 and C21) in the amplifier's circuits transform the amplifiers into low-pass filters. These filters attenuate any high-frequency noise that may be present in a signal. The filter characteristics depend on the resistors selected. The 3 dB corner frequency is

$$f_{3\text{db}} = \frac{1}{2\pi \times R_g \times 0.01 \mu\text{F}} \quad (3-1)$$

For the above case with a gain of 0.25 using a 1% feedback resistor of 2370 Ω , the 3 dB corner frequency is 6715 kHz.

Internal Test Voltages

By addressing “virtual” channels in the A/D converter, Dynamic C routines can obtain internal test voltages from the A/D converter. However, these readings measure VREF+ and VREF- with respect to VREF and GND so that the resulting conversions are all 0s or all 1s.

Drift

The AD680JT voltage reference exhibits a voltage drift of 10 ppm/ $^{\circ}\text{C}$ (typ) to 30 ppm/ $^{\circ}\text{C}$ (max). This drift corresponds to 25 $\mu\text{V}/^{\circ}\text{C}$ to 75 $\mu\text{V}/^{\circ}\text{C}$, or 1.75 mV to 5.25 mV over the temperature range of 0 $^{\circ}\text{C}$ to 70 $^{\circ}\text{C}$.

The LMC662C operational amplifier exhibits an offset-voltage drift of 1.3 $\mu\text{V}/^{\circ}\text{C}$ (typ), or 910 μV over the temperature range.

A greater contribution to overall drift arises from differences in the temperature coefficients of the user-installed gain and bias resistors and the fixed 10 k Ω resistors R21–R24. Resistors R21–R24 have temperature coefficients of ± 200 ppm/ $^{\circ}\text{C}$. Because they are small, surface-mount resistors, and are close to each other, they are always at essentially the same temperature and their temperature deviations track closely.

Absolute and Ratiometric Modes

The A/D converter can operate in either an absolute or a ratiometric mode.

- In absolute mode, the A/D converter compares the input signal against an accurate, stable onboard reference. The onboard voltage-reference is an AD680JT, which has a drift specification of 10 ppm/ $^{\circ}\text{C}$ (typical).
- In ratiometric mode, both the reference voltage and the voltage for the sample are connected to the same power supply. Because the reference voltage and the sample voltage experience the same power supply fluctuations, the ratiometric mode minimizes errors in certain types of measurements, specifically those measurements where the BL1500 has to supply an excitation voltage to a bridge or transducer.

The BL1500's A/D converter is factory configured to operate in the absolute-conversion mode using a precision onboard voltage reference (an AD680, U4, or an LM385, U5) as shown in Figure 3-6. REF- is hard-wired to ground. REF+ connects to one of two sources of 2.5 V.

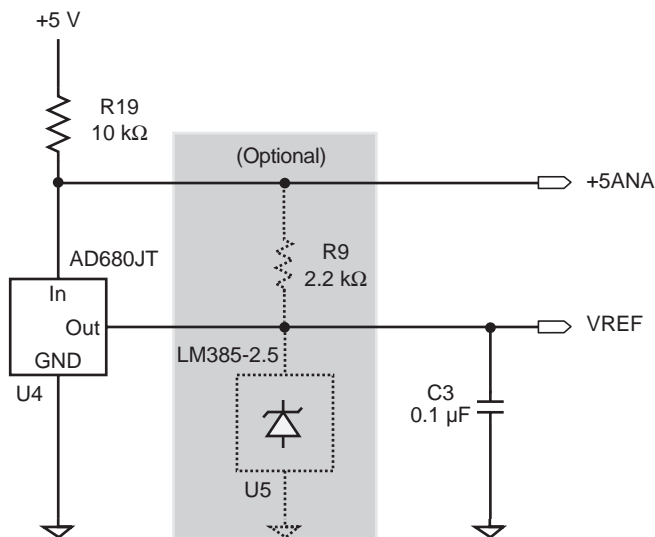


Figure 3-6. Analog Reference in Absolute Conversion Mode

U4 (or U5) may be removed and voltage-dividing resistors R9 and R10 may be added to change the BL1500 to the ratiometric mode. The axial-lead resistors at R9 and R10 form a voltage divider to supply REF+. Figure 3-7 shows the locations of the components to be changed, and the resulting circuit is shown in Figure 3-8.

For the ratiometric-conversion mode, you need to know the resistor values used in the op-amp circuit before you can determine the values you need to install for R9 and R10.

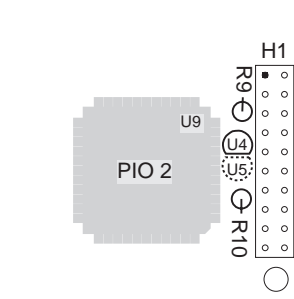


Figure 3-7. Location of Analog Reference Components for Ratiometric Conversion



REF+ is also the reference voltage for the op-amps used with A/D channels 0 and 1. The resistors of the op-amp bias circuit will interact with the R9/R10 voltage divider to affect the actual value of REF+.

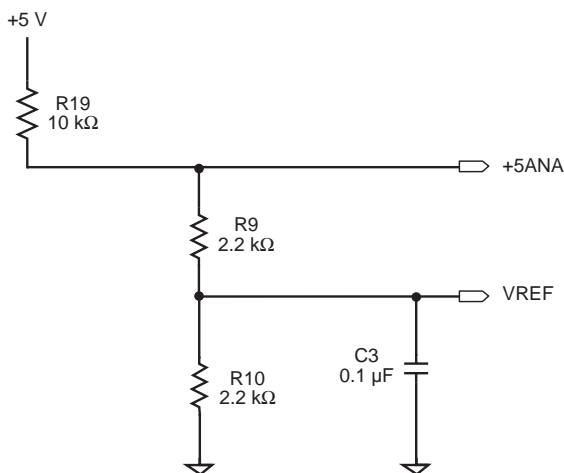


Figure 3-8. Analog Reference in Ratiometric Conversion Mode

Bipolar or Unipolar Conditioned Inputs

The two conditioned inputs can be used to measure bipolar or unipolar signals. The inputs for the two conditioned channels, AD0 and AD1, are pins 18 and 20 of header H1. The unconditioned inputs, AD2 and AD3, use pins 15 and 16 of header H1.

Signals from sensors connected to AD0 and AD1 of H1 go to the inverting input of one of the two op-amps in U16. U16's op-amps operate in the inverting configuration. User-selectable resistors R11 through R14 set the gain and bias voltages of the amplifiers. The 10 kΩ input and bias resistors (R21 through R24) are fixed. Feedback capacitors C20 and C21 roll off the high-frequency response of the amplifiers to attenuate noise.

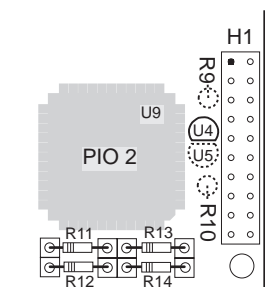


Figure 3-9. Location of Gain and Bias Resistors

Figure 3-9 shows the location of the gain and bias resistors (R11–R14) used to condition the analog input.

Factory-Installed Gain and Bias Resistors

The BL1500 is configured with gain and bias resistors installed for the conditioned A/D channels (configured for 0 V to 10 V DC inputs) so that the controller works right out of the box. If a different input voltage range is required, change the gain and bias resistors.

Initial Setup

The op-amp's gain and bias resistors, R11–R14, are installed in sockets provided on the BL1500. Each BL1500 controller comes with these resistors already installed.

- R_{GAIN} : R11 and R13 = 2370 Ω
- R_{BIAS} : R12 and R14 = 39.2 k Ω

Resistors R11–R14 yield a nominal gain of 0.25 for a unipolar input signal ranging from 0 V to 10 V. These values differ slightly from theoretical values to allow for real-world resistor tolerances.



Refer to “Setting Up Conditioned Inputs” on the following pages for a detailed method of determining the best values for gain and bias resistors.

The strip sockets on 0.300-inch centers accommodate 1/8 W resistors R11–R14.



The BL1500 can be ordered in production quantities with customer-specified surface-mount resistors installed for R11–R14. Contact your Z-World Sales Representative at (530) 757-3737.

Representative Analog-to-Digital Setups

Table 3-7 gives the values of gain and bias resistors for various common input-voltage ranges in the absolute-conversion mode using the onboard voltage reference. These values, which require standard 1% resistors, have been adjusted from theoretical values to account for tolerance variations. If one of these setups does not suit your application, proceed to the next section and follow the design method presented there to calculate the resistor values required.

Table 3-7. Gain and Bias Resistor Input Voltage Ranges

Input Range (V)	Gain	R _{GAIN} (k Ω)	R _{BIAS} (k Ω)
-10.0 to +10.0	0.125	1.18	8.06
-5.0 to +5.0	0.250	2.37	6.65
-2.5 to +2.5	0.500	4.75	4.99
-2.0 to +2.0	0.625	5.90	4.53
-1.0 to +1.0	1.250	11.8	2.87
-0.5 to +0.5	2.500	23.7	1.69
-0.25 to +0.25	5.000	47.5	0.931
-0.10 to +0.10	12.500	118	0.392
0 to +10.0	0.250	2.37	39.2
0 to +5.0	0.500	4.75	20.0
0 to +2.5	1.000	9.53	10.0
0 to +1.0	2.500	23.2	4.02

Setting Up Conditioned Inputs

The gain and bias resistors (R11–R14) determine the input signal's voltage relative to ground as well as its range. For example, assume a circuit must handle an input signal range of 10 V spanning -5 V to +5 V. Given this specification, note the following points regarding resistor sizing.

- Select the gain resistor, R_{GAIN} (R11 or R13), to suit your input signal voltage range of 10 V.
- The gain of the amplifier is the ratio of its maximum output voltage swing to an application's maximum input voltage swing. The fixed 2.5 V input range of the A/D converter limits the op-amp's output swings to 2.5 V.

Equation (3-2) expresses an amplifier's gain in terms of its input voltage range, where g is the gain, $V_{IN_{max}}$ is the maximum input voltage, and $V_{IN_{min}}$ is the minimum input voltage.

$$g = \frac{2.5 \text{ V}}{V_{IN_{max}} - V_{IN_{min}}} \quad (3-2)$$

- The ratio of the user-specified gain resistor R_{GAIN} (R11 or R13) to its associated fixed input resistor (R21 or R23) determines an amplifier's gain. For the amplifier in Figure 3-10 with its input resistor fixed at 10 k Ω , the gain is

$$g = \frac{R_{GAIN}}{10 \text{ k}\Omega} \quad (3-3)$$

- Given an input voltage range of 10 V, this gain equation fixes the amplifier's gain at 0.25, and scales the input signal's range properly down to the op-amp's 2.5 V maximum output range. R_{GAIN} must therefore be 2500 Ω .

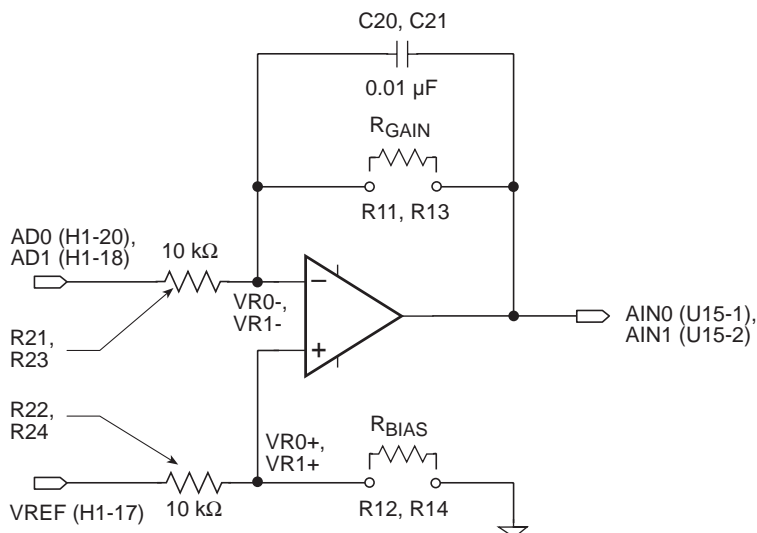


Figure 3-10. Gain and Bias Resistors for Conditioned Analog Inputs

Determine Bias Resistor To Center Span

If the op-amp is to servo its output properly around the desired center voltage, establish the appropriate bias voltage at the op-amp's noninverting input. Select the bias, or offset, resistor R_{BIAS} (R12 or R14) to position the input voltage range correctly with respect to ground (in this example, -5 V to +5 V).

Because the value for R_{GAIN} has already been selected, the maximum input voltage (V_{INmax}) determines the maximum input voltage seen at the amplifier's summing junction (inverting input), circuit nodes VR0- and VR1-. Compute VR0- or VR1- using Equation (3-4).

$$VR0- = V_{INmax} \times \left(\frac{g}{1+g} \right) . \quad (3-4)$$

The bias voltage (V_{BIAS}) must equal its corresponding VRn- for each op-amp. A voltage divider, comprising a bias resistor R_{BIAS} (R12 or R14) and a fixed 10 k Ω resistor (R22 or R24), derives this bias voltage ($V_{BIAS} = VR0+$ or $VR1+$) from VREF, the 2.5 V reference voltage. Equation (3-5) gives R_{BIAS} .

$$R_{BIAS} = \frac{V_{BIAS} \times 10 \text{ k}\Omega}{2.5 \text{ V} - V_{BIAS}} . \quad (3-5)$$

The 2.5 V term in the Equation (3-5) denominator is the reference voltage. The low-impedance voltage reference supplies this voltage when the BL1500 is in the absolute conversion mode.

When the BL1500 is being used in the ratiometric mode, the optional resistive divider R9–R10 supplies this voltage. But, in this case, the op-amp's bias resistors R12, R22, R14, and R24 load the divider (more correctly, the bias resistors are, in effect, part of the divider in parallel with R10). Therefore, first compute values for R12, R22, R14, and R24, assuming that VREF is 2.5 V. Then compute the required values of R9 and R10 that derive a reference voltage of 2.5 V while taking into account the resistance of R12, R22, R14, and R24.

Unipolar Variation

Suppose the input range is 0 V to +10 V instead of -5 V to +5 V. V_{INmax} is now +10 V, V_{BIAS} becomes 2.0 V, and R_{BIAS} is 40 k Ω .

Choose Best Standard Resistor Values

Calculated values are not always be available as standard resistor values. In these cases, use the nearest standard resistor value. For example, rather than 6667 Ω , use 6650 Ω if using one percent resistors, or 6800 Ω if using 5 percent resistors.

Bracketing Input Range

To be sure of accurately measuring signals at the extremes of an input range, be aware of the interaction between the 10 k Ω fixed resistors R21–R24 and the other installed resistors R11–R14. In the ideal case, if a signal is measure at the minimum input level, the A/D converter's input would be at the maximum expected value of 2.5 V.

Resistor values vary within their rated tolerance bands. Thus, if the fixed input resistor is lower than its nominal value, and the installed resistor is slightly higher than its nominal value, the actual input to the A/D converter would be greater than 2.5 V. A loss of accuracy then results because the A/D input would reach its maximum input value before the true signal input reaches the minimum expected input level.

Figure 3-11 shows how variations in tolerance can cause the analog signal to exceed the limits of the analog converter.

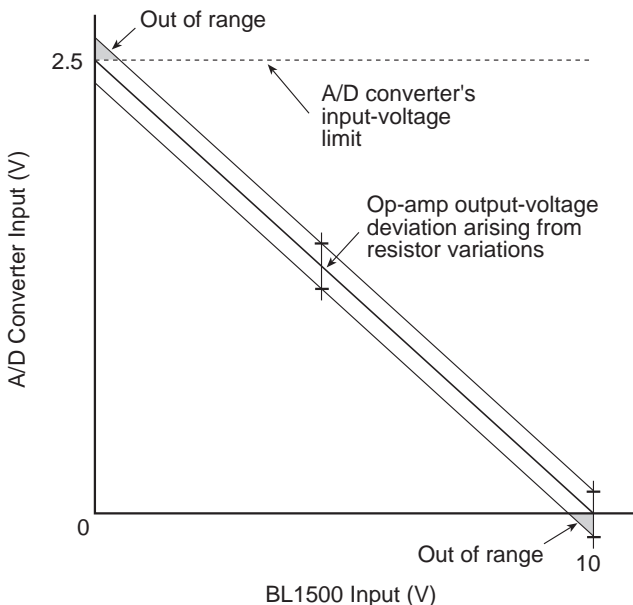


Figure 3-11. A/D Converter Input Ranges Out of Range Based on Resistor Variation

A deviation from nominal values in the bias network could skew the A/D converter's input voltage away from a theoretically computed value. For example, a small positive or negative deviation of the bias voltage arising from variances in the resistive divider would offset the A/D converter's input voltage. This offset would be positive or negative, tracking the deviation's sign, and equal to the bias deviation multiplied by the amplifier's gain plus one. Both of these effects could occur in the same circuit.

Pick Proper Tolerance

Use care when compensating for any discovered discrepancies. For example, if standard 5% resistors are used for R11–R14, remember that their values are spaced approximately 10% apart.



The tolerance is plus or minus 5%; therefore, any value calculated will be within plus or minus 5% of a standard value.

If a gain is too high by just a small amount, then going to the next smallest standard 5% value could result in a decrease in gain approaching 10%. The same caveat applies to the bias network. Use 1% resistors to get a more precise choice of values.

Figure 3-12 illustrates the results of adjusting the resistor values so that the input to the A/D converter stays within its specified range of 2.5 V.

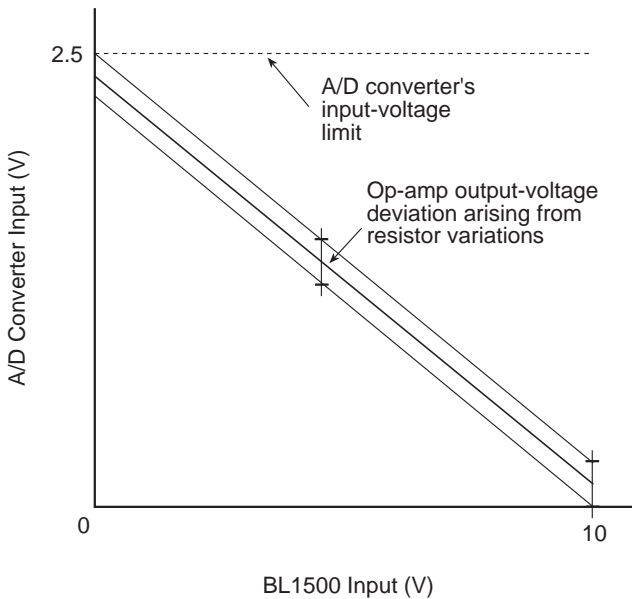


Figure 3-12. A/D converter Input Ranges Within Range Based on Resistor Variations



Use the mathematically derived values if the loss of signal range is acceptable.

Confirm Performance

If measurements are critical, check the setups after installing resistors by measuring test signals at and near the input-voltage limits. See if the voltages fall within the A/D converter's input range or if loss of accuracy occurs because of overexcursions at the A/D converter's input. Alternatively, measure the resistance of the factory-installed fixed resistors before selecting and measuring your own resistors.

Fixed resistors can be measured indirectly after being installed by measuring the voltages at the amplifier's inputs and outputs. Using Channel 0 as an example, ground the input AD0 at pin 20 of H1. Then measure the voltages at VR0- and the amplifier's output. The voltage test points are shown in Figure 3-13, and their location on the BL1500 is shown in Figure 3-9.

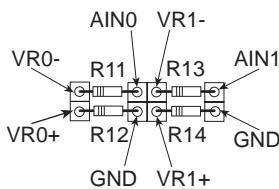


Figure 3-13. Voltage Test Points

Because the currents through the input resistor and the feedback resistor are essentially identical, the ratio of the voltages across the resistors is equivalent to the ratio of the resistors. Therefore, the gain is as displayed in Equation (3-6).

Similarly, again using Channel 0 as an example, measure the voltage of VREF (pin 17 on header H1) and the voltage at VR0+ (see Figure 3-13).

$$\text{gain} = \frac{\text{VOUT} - \text{VR0-}}{\text{VR0-}} \quad (3-6)$$

Because the current into the op-amp input is negligible, the resistance ratio of the two resistors in the voltage divider alone determines VR0+. Once both the value of the installed resistor and the value of VR0+ are known, compute the value of the fixed resistor in the divider.

Calibrating the A/D Converter

The inherent component-to-component variations of 5% or 1% resistors can “swamp” the 0.25% resolution of the A/D converter. To achieve the highest accuracy possible, calibrate the BL1500.

The software drivers for the A/D converter provide routines to compute calibration coefficients (given two reference points) and store them in a defined location in nonvolatile memory. Each reference point is determined from the following pair of values:

1. The actual applied test voltage.
2. The raw converted A/D value (a 12-bit integer).

Dynamic C automatically uses these coefficients to correct all subsequent A/D readings.

Dynamic C automatically uses these coefficients to correct all subsequent A/D readings. Table 3-8 lists the addresses in simulated EEPROM where the calibration constants are stored.

Table 3-8. A/D Converter Calibration Constants

Address in Simulated EEPROM	A/D Channel
10–15	0
16–21	1
22–27	2
28–33	3

Using Unconditioned Converter Channels

Two additional input channels of the A/D converter (AD2 and AD3) are available at pins 15 and 16 on header H1. These channels can be accessed with software by inserting the appropriate channel number in the library functions that control the A/D converter.

Resistors R0 and R1 (10 k Ω pullup resistors) inside resistor network RN3 are connected to these two A/D channel inputs to ensure that the inputs do not float if no input signals are present. These pullup resistors can also be used as excitation resistors if the sensor or transducer being used needs a resistor connected to the voltage supply. Each input also has a 330 Ω series resistor in place to guard against latch-up in the A/D converter. This value is within the 1000 Ω maximum source driving resistance that the A/D converter manufacturer specifies as being adequate to charge the converter’s internal sample-and-hold capacitors.

Figure 3-14 illustrates these additional A/D converter input channels.

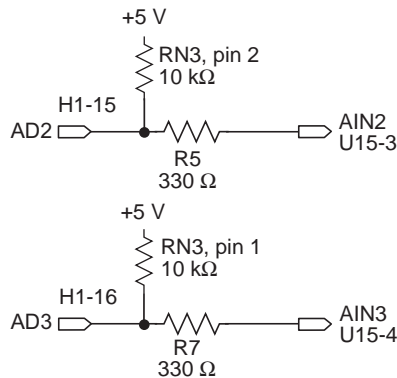


Figure 3-14. A/D Converter Input Channels AD2 and AD3

To prevent latchup, note the following important guidelines.

1. Do not apply voltages to the A/D converter's inputs greater than VCC or less than GND.
2. Do not apply input voltages to the BL1500's A/D channels before powering up the board.
3. Do not apply analog signals to the BL1500 before it is powered up.

For optimum results, drive the unconditioned channels with low-impedance voltage sources. Operational amplifiers are ideal for this purpose. High-impedance signals sources, on the other hand, are susceptible to coupled noise and distort when loaded by the 10 k Ω pullup resistors.

When designing the signal sources to drive the two channels, be sure to consider whether the chosen amplifiers can handle the capacitance of the cable that connects to H1.

Real-Time Clock

The BL1500 has a real-time clock (RTC). However, the RTC is an optional feature for the BL1510 and BL1520. The RTC (U14) provides time and date functions plus 31 bytes of scratchpad RAM. The RTC also has the following features.

- Automatically adjusts the last date of the month for the number of days in a month and accounts for leap years.
- Reports time in either 24-hour or 12-hour format (a.m or p.m. indicated).
- An external battery (2.5 V to 4.25 V DC) allows the RTC to retain its time and data when power fails.

The RTC has a trickle-charge circuit to charge a rechargeable battery or super capacitors. The trickle-charge register controls the trickle-charge circuit and disables the circuit on power-up.



If you are using a nonrechargeable battery to back up the RTC, do **not** enable the trickle-charge circuit. Enabling the trickle-charge circuit may cause the battery to explode.



*CHAPTER 4: **SYSTEM DEVELOPMENT***

Chapter 4 describes how to use and/or implement features of the BL1500. Sections include the following topics.

- Starting Development
- Operating Modes
- Running a Program Standalone
- Returning to Programming Mode
- Developing a Communications Network

Beginning Development

Before beginning development, check the following items.

- Verify that the BL1500 runs in standalone mode before connecting any expansion boards or I/O devices.
- Verify that the entire host system has a good, low-impedance, separate grounds for analog and digital signals. Often the BL1500 is connected between the host PC and another device. Any differences in ground potential from unit to unit can cause serious problems that are hard to diagnose.
- Do not connect analog ground to digital ground anywhere.
- Double-check the connecting cables to ensure that none are plugged backwards into the BL1500's headers.
- Verify that the host PC's COM port works by connecting a good serial device to the COM port. Remember that on a PC, COM1/COM3 and COM2/COM4 share interrupts. User shells and mouse drivers, in particular, often interfere with proper COM port operation. For example, a mouse running on COM1 can preclude running Dynamic C on COM3.
- Use the supplied Z-World power supply. If another power supply must be used, verify that it has enough capacity and filtering to support the BL1500.
- Use the supplied Z-World cables. The most common fault of user made cables is failure to properly assert CTS at the RS-232 port of the BL1500. Without CTS being asserted, the BL1500's RS-232 port will not transmit. Assert CTS by either connecting the RTS signal of the PC's COM port or looping back the BL1500's RTS. If wiring up a DB9 connector or a RJ-12 connector to a 10-pin connector, check the connections carefully. The wires do not run pin-for-pin. Note also that telephone-company wiring does not really follow a standardized color code.
- Experiment with each peripheral device connected to the BL1500 in order to determine how it appears to the BL1500 when powered up, powered down, and/or when its connecting wiring is open or shorted.

Operating Modes

The BL1500 has two operating modes that are mutually exclusive, Run Mode and Program Mode. Each mode is explained in detail below.

Program Mode

In Program Mode, the BL1500 controller runs under the control of a host PC that is running Dynamic C. The BL1500 must be in Program Mode when attempting to compile a program to it or to debug a program.



The BL1500 matches the baud rate of a PC's COM port up to 57,600 bps. Possible baud rates are 9600 bps, 19,200 bps, 28,800 bps, and 57,600 bps.

Run Mode

In Run Mode, the BL1500 controller runs standalone. Upon power-up, the BL1500 checks to see if its onboard memory contains a program. If a program exists, the BL1500 controller executes the program immediately after power-up.



The BL1500 does not respond to Dynamic C running on a host PC. A program cannot be compiled or debugged when the BL1500 is in Run Mode.

Running A Program in Run Mode

Use the following steps to run a program standalone (not under Dynamic C control).

1. Download the compiled program to flash EPROM.



See Chapter 5, "Software Reference," for details on the **WriteFlash** function to read or write to flash EPROM.

2. Disconnect power to the BL1500.
3. Remove either the SIB2 or the jumper from pins 1 and 2 of header J1, depending on the programming mode used.
4. Reapply power. The BL1500 begins automatically executing the program.

Returning To Programming Mode

Use the following steps to return to programming mode:

1. Disconnect power.
2. Reinstall the jumper connecting pins 1 and 2 of header J1 or reconnect the SIB2.
3. Reapply power.

EPROM

The BL1500 has a 32-pin socket (U6) that accepts 32K to 512K EPROMs. The socket accepts either 28-pin or 32-pin EPROM chips, including the following.

27C256	32K	28 pins
27C512	64K	28 pins
27C010	128K	32 pins
27C020	256K	32 pins

When using a 28-pin EPROM, four pin positions at one end of the socket are left empty, as shown in Figure 4-1. The access time must be 100 ns or better at 9 MHz.

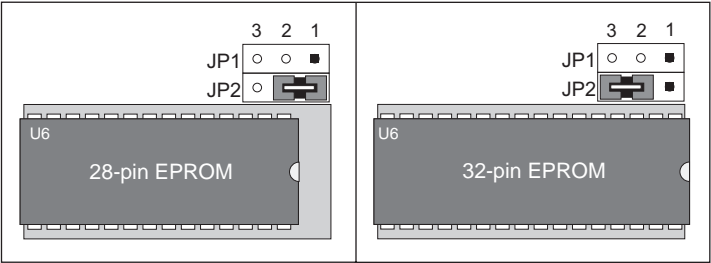


Figure 4-1. 28-pin and 32-pin EPROM Placement

Header JP1 reflects whether the EPROM is flash or non-flash, and header JP2 reflects the EPROM size, as shown in Figure 4-2.

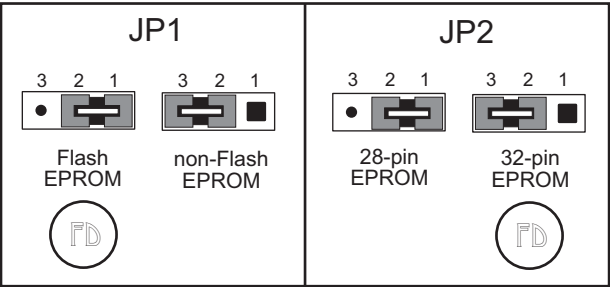


Figure 4-2. BL1500 EPROM Jumper Configurations

The BL1500 is able to handle both flash and non-flash EPROM.

Programming EPROM

Dynamic C can be used to create a file for programming an EPROM by selecting the **Compile to File** option in the **COMPILE** menu with the flash EPROM in the Developer's Kit installed. The BL1500 must be connected to the PC running Dynamic C during this step because essential library routines must be uploaded from the flash EPROM and linked to the resulting file. The output is a binary file (optionally an Intel hex format file) that can be used to build an application EPROM. The application EPROM is then programmed with an EPROM programmer that reads either a binary image or the Intel hex format file. The resulting application EPROM can then replace the flash EPROM.

Copyrights

The Dynamic C library is copyrighted. Place a label containing the following copyright notice on the EPROM whenever an EPROM that contains portions of the Dynamic C library is created.

©1998 Z-World

Your own copyright notice may also be included on the label to protect your portion of the code.

Z-World grants purchasers of the Dynamic C software and the copyrighted BL1500 EPROM permission to copy portions of the EPROM library as described above, provided that:

1. The resulting EPROMs are used only with the BL1500 manufactured by Z-World, and
2. Z-World's copyright notice is placed on all copies of the EPROM.

Developing An RS-485 Network

Any one of Z-World’s controllers can be a master or a slave. While a network can have up to 255 slave controllers, only one controller can be the master.

The two-wire RS-485 serial-port and Dynamic C allow network development. Header H3 provides a half-duplex RS-485 interface. The RS-485 signals are on pins 23 and 24 of header H3, and also on pins 23 and 24 of header H2 on the Prototyping Board (see Figure 4-3).

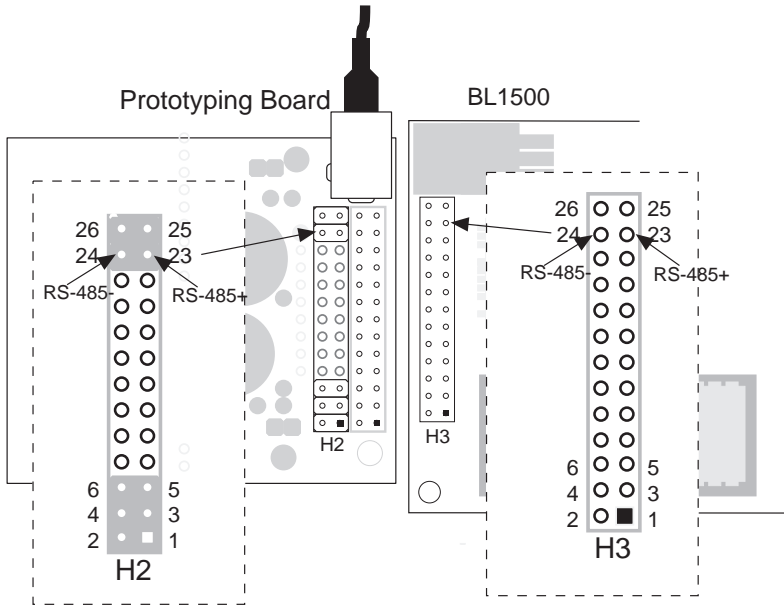


Figure 4-3. Locations on RS-485 Signals on BL1500

The BL1500 and other controllers can be linked together over several kilometers. When configuring a multidrop network, use single twisted-pair wires (not stranded, tinned) on all controllers to connect RS-485+ to RS-485+ and RS-485- to RS-485- as shown in Figure 4-4.

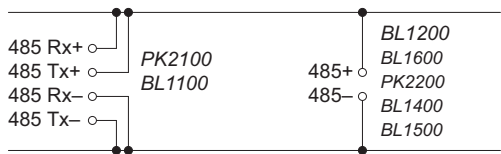


Figure 4-4. Two-Wire RS-485 Network Connections

Figure 4-5 provides a diagram of a two-wire RS-485 network.

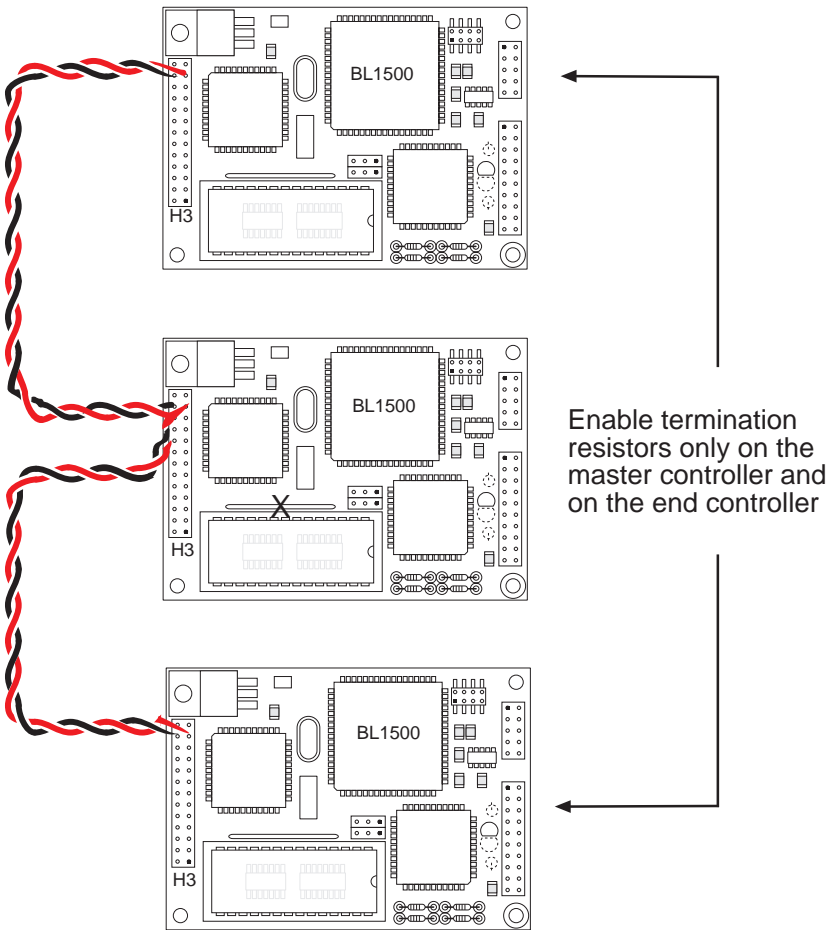


Figure 4-5. BL1500 RS-485 Network

Termination and bias resistors are required in a multidrop network to minimize reflections (echoing) and to keep the network line active during an idle state. Only the first and last board on a multidrop RS-485 cable should have termination resistors. Therefore, when networking multiple boards on an RS-485 network, remove resistor pack RP1 (shown in Figure 4-6) from all boards in the network, except for the first and last board of the network (see Figure 4-5).

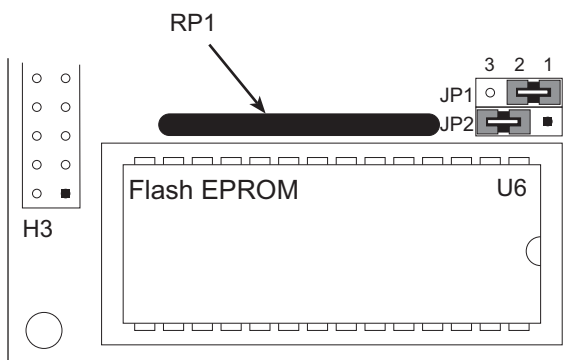


Figure 4-6. RP1 Termination Resistor Pack Location



CHAPTER 5: *SOFTWARE REFERENCE*

The functions described in this chapter operate the BL1500 input/output interfaces. Most required functions are in the **BL14_15.LIB** library; however, others are found in the Dynamic C BIOS in the BL1500's onboard flash EPROM.

Sections in this chapter include the following topics.

- Software Development Options
- Programmable Inputs/Output
- Input/Output Software
- Real Time Clock Software
- Analog-to-Digital Converter Drivers
- Controlling XP8300 with PIO 1 Port A and Port B
- Using a Liquid Crystal Display
- Using a Keypad with PIO Port A and Port B
- Nonvolatile Storage
- Support Libraries and Sample Programs

Software Development Options

BL1500 controllers use a flash EPROM for code development. Two sizes of flash EPROM are available from Z-World: 128K and 256K. Current technology limits the size of flash EPROM in the BL1500 series to a maximum of 256K.

Code can be developed on the BL1500 series by using either the RS-232 port or the Serial Interface Board 2 (SIB2) port. However, the SIB2 port is a dedicated programming port, and so using it for programming leaves the RS-232 port free for the embedded application.

Dynamic C Development Software

Two versions of Z-World's Dynamic C development software are currently available for the BL1500 running under Microsoft Windows.

- **Standard:** Maximum 80K of code.

This version of Dynamic C is suitable for programs up to 80K with limited access to extended memory (you cannot declare data items in extended memory).

- **Deluxe:** Maximum 512K of code, 512K of data.

This version supports programs (up to 512K code and 512K data) with full access to extended memory.

Dynamic C Manuals

Z-World offers three Dynamic C manuals for programming reference.

- *Dynamic C Technical Reference*
- *Dynamic C Application Frameworks*
- *Dynamic C Function Reference*

Programmable Input/Output

The BL1500 has two PIO chips having a total of 32 individual digital, programmable I/O lines.

Table 5-1 lists the names that Dynamic C defines as macros in its software libraries. These macros are the PIO I/O-data register and command register addresses. Do not define these macros in your application.

Table 5-1. PIO Register Names

Register Name	Function
PIOCA	Command register for Port A of PIO 1
PIOCB	Command register for Port B of PIO 1
PIODA	Data register for Port A of PIO 1
PIODB	Data register for Port B of PIO 1
PIOCA2	Command register for Port A of PIO 2
PIOCB2	Command register for Port B of PIO 2
PIODA2	Data register for Port A of PIO 2
PIODB2	Data register for Port B of PIO 2

By default, names related to PIO 1 do not explicitly designate the PIO number; however, names related to PIO 2 do indicate the number. This scheme ensures software compatibility with the BL1400, which only has a single PIO chip. For example, observe the names of I/O routines that use “shadow registers”: **PIOCAShadow** and **PIOCBShadow** for PIO 1 and **PIOCA2Shadow** and **PIOCB2Shadow** for PIO 2.

Available PIO Lines

Not all I/O and handshaking lines of the two PIO chips are available for use. The following sections describe the available lines.

- **PIO 1 I/O lines**

PIO 1 Port A is available (all 8 bits) in PIO modes 0 (strobed-byte input), 1 (strobed-byte input), and 3 (bitwise I/O).

PIO 1 Port B is available in mode 3 (bitwise I/O) only. Bits 7–4 of Port B are always available. Bits 3 (RTCCLK) and 2 (RTCDAT) are available if the real-time clock (RTC) is not used. (The RTC is not present on the standard BL1510 and the BL1520.) Bits 1 (EN485) and 0 (/RTCRST) of Port B are dedicated lines.

- **PIO 2 I/O lines**

PIO 2 Port A is available (all bits) in PIO mode 3 only.

PIO 2 Port B is available in mode 3 only. Bits 7–4 of Port B are always available. Bit 3 (EOCNMI) is the logical conjunction of /NMI and EOC. Bit 2 (ADDOUT), bit 1 (ADDIN), and bit 0 (ADCLK) are hard-wired to the A/D converter.

Power-up PIO Configuration

On power-up, the BL1500's onboard Dynamic C BIOS configures both PIOs' Ports A and Ports B to mode 3 (bitwise-I/O mode) with all bits as inputs.

Input/Output Software

A choice of I/O routines is available. A complete subset of I/O routines maintains and uses “shadow registers,” **PIOCAShadow** and **PIOCBShadow** for PIO 1, and **PIOCA2Shadow** and **PIOCB2Shadow** for PIO 2.

Shadow Registers

Shadow registers are a standard embedded-systems programming technique. Some of the functions that manipulate the hardware I/O ports automatically keep a copy of each register’s current configuration. If writing routines (especially interrupt service routines) that temporarily change the configuration of any hardware I/O port, the interrupt routines first save the appropriate shadow registers before changing the ports, and then restore the ports to their original configuration before exiting, using the saved contents of the shadow-registers.

Function Prototypes

The following function descriptions follow standard C notation for “function prototypes.” Function prototypes are not examples of how to use a given function. Instead, they modify the names, parameters, and arguments of functions with a C-type specifier such as **void**, **byte**, and **int**. In addition, some function prototypes use dummy arguments for parameters. When using these functions in an application program, do not include the type specifiers, instead replace the applicable dummy arguments with your own defined arguments.



In the following descriptions, the term **void** means that the function returns no value. **Void** cannot be used as an operand.

- **void setPIOCA(byte mask)**

PIOCA ← **PIOCAShadow** ← **PIOCAShadow OR mask**

Active bits (1s) of **mask** are set in **PIOCAShadow**. That result goes to **PIOCA**. Active bits becomes input bits. PIO 1.

- **void resPIOCA(byte mask)**

PIOCA ← **PIOCAShadow** ← **PIOCAShadow AND NOT mask**

Active bits (1s) of **mask** are reset in **PIOCAShadow**. That result is then sent to **PIOCA**. Active bits becomes output bits. PIO 1.

- **void setPIODA(byte mask)**

PIODA ← **PIODA OR mask**

Active bits (1s) of **mask** are set in the current output of **PIODA**. PIO 1.

- **void resPIODA(byte mask)**

$$\text{PIODA} \leftarrow \text{PIODA} \text{ AND NOT } \text{mask}$$

Active bits (1s) of **mask** are reset in the current output of **PIODA**. PIO 1.
- **void setPIOCB(byte mask)**

$$\text{PIOCB} \leftarrow \text{PIOCBShadow} \leftarrow \text{PIOCBShadow OR mask}$$

Active bits (1s) of **mask** are set in **PIOCBShadow**. That result is then sent to **PIOCB**. Active bits become input bits. PIO 1.
- **void resPIOCB(byte mask)**

$$\text{PIOCB} \leftarrow \text{PIOCBShadow} \leftarrow \text{PIOCBShadow AND NOT mask}$$

Active bits (1s) of **mask** are reset in **PIOCBShadow**. That result is sent to **PIOCB**. Active bits become output bits. PIO 1.
- **void setPIODB(byte mask)**

$$\text{PIODB} \leftarrow \text{PIODB OR mask}$$

Active bits (1s) of **mask** are set in the current output of **PIODB**. PIO 1.
- **void resPIODB(byte mask)**

$$\text{PIODB} \leftarrow \text{PIODB AND NOT mask}$$

Active bits (1s) of **mask** are reset in the current output of **PIODB**. PIO 1.
- **void setPIOCA2(byte mask)**

$$\text{PIOCA2} \leftarrow \text{PIOCA2Shadow} \leftarrow \text{PIOCA2Shadow OR mask}$$

Active bits (1s) of **mask** are set in **PIOCA2Shadow**. That result is then sent to **PIOCA2**. Active bits become input bits. PIO 2.
- **void resPIOCA2(byte mask)**

$$\text{PIOCA2} \leftarrow \text{PIOCA2Shadow} \leftarrow \text{PIOCA2Shadow AND NOT mask}$$

Active bits (1s) of **mask** are reset in **PIOCA2Shadow**. That result is then sent to **PIOCA2**. Active bits become output bits. PIO 2.
- **void setPIODA2(byte mask)**

$$\text{PIODA2} \leftarrow \text{PIODA2 OR mask}$$

Active bits (1s) of **mask** are set in the current output of **PIODA2**. PIO 2.
- **void resPIODA2(byte mask)**

$$\text{PIODA2} \leftarrow \text{PIODA2 AND NOT mask}$$

Active bits (1s) of **mask** are reset in the current output of **PIODA2**. PIO 2.

- **void setPIOCB2(byte mask)**

$$\text{PIOCB2} \leftarrow \text{PIOCB2Shadow} \leftarrow \text{PIOCB2Shadow OR mask}$$

Active bits (1s) of **mask** are set in **PIOCB2Shadow**. Active bits become input bits. PIO 2.
- **void resPIOCB2(byte mask)**

$$\text{PIOCB2} \leftarrow \text{PIOCB2Shadow} \leftarrow \text{PIOCB2Shadow AND NOT mask}$$

Active bits (1s) of **mask** are reset in **PIOCB2Shadow**. That result is then sent to **PIOCB2**. Active bits become output bits. PIO 2.
- **void setPIODB2(byte mask)**

$$\text{PIODB2} \leftarrow \text{PIODB2 OR mask}$$

Active bits (1s) of **mask** are set in the current output of **PIODB2**. PIO 2.
- **void resPIODB2(byte mask)**

$$\text{PIODB2} \leftarrow \text{PIODB2 AND NOT mask}$$

Active bits (1s) of **mask** are reset in the current output of **PIODB2**. PIO 2.

Real-Time Clock

The real-time clock (RTC) has the following features.

- A clock/calendar that accounts for leap years and the varying number of days in a month.
- A 31-byte scratchpad RAM.
- The capability to recharge the backup battery (2.5 V to 4.25 V DC) if a user-supplied backup battery is attached to the BL1500.



Do not enable the real-time clock's trickle charger if a nonrechargeable device is attached. The device could explode.

An application can write to both the clock/calendar and the RAM in “burst mode.” In this mode, the software specifies a start location and then writes multiple, consecutive characters to the RTC. The RTC automatically increments the internal address for the next write. This approach is more efficient than setting the address for each byte in the nonburst mode.

Global Time and Date Structure

Dynamic C automatically creates the following global structure to hold the time and date.

```
struct tm{
    char tm_sec;           // 0-59
    char tm_min;           // 0-59
    char tm_hour;          // 0-23
    char tm_mday;          // 1-31
    char tm_mon;           // 1-12
    char tm_year;          // 0-150 (1900-2050)
    char tm_wday;          // 0-6 where 0 means Sunday
};
```



Because Dynamic C automatically creates this structure, it should not be declared in an application.

Function Prototypes

- **int tm_rd(struct tm *t)**

Stores the real-time clock's current contents into the structure ***t**.

If the RTC is halted, this function stores the value for midnight, January 1, 1980 in ***t**, and returns -1. Otherwise the function stores the current time in ***t** and returns 0.

- **int tm_wr(struct tm *t)**

Writes the values in the structure ***t** to the RTC.

The function returns 0 if successful, or -1 if it is unable to start the RTC.

- **int WriteRam1302(int ram_loc, byte data)**

Writes data to any of the 31 (0-30) RAM locations of the DS1302.

The function returns 1 if successful and -1 if **ram_loc** is out of range.

- **int ReadRam1302(int ram_loc)**

Reads data from any of the 31 (0-30) RAM locations of the DS1302.

The result of the function is the data value or -1 if **ram_loc** is out of range.

- **void WriteBurst1302(void* pdata, int count)**

Writes **count** bytes, in burst mode, to the DS1302, starting at RAM location 0.

The term **pdata** points to the data.

- **void ReadBurst1302(void* pdata, int count)**

Reads **count** bytes, in burst mode, from the DS1302, starting at RAM location 0.

The term **pdata** points to a storage area for the data.

- **void Write1302(int reg, byte data)**

Writes data to a specified register of the DS1302.

- **int Read1302(int reg)**

Reads data from a specified register of the DS1302.

The result of the function is the data value.

- **Charger1302(int on_off, int diode, int resistor)**

Turns the trickle charger on the DS1302 on (when **on_off** is non-zero) or off (when **on_off** is 0).

The term **diode** is 1 or 2 for the number of diodes in the charging circuit.

The term **resistor** is 2, 4, or 8 for the resistance (k Ω) in the circuit.



If a “super capacitor” or a rechargeable battery (2.5 V to 4.25 V DC) is connected to the BL1500 (across U14’s VBAT and GND), the RTC continues to run and its scratchpad-RAM data are not lost when power is removed from the BL1500.



If a nonrechargeable battery (2.5 V to 4.25 V DC) is attached to the BL1500, do not enable the DS1302’s trickle-charge circuit or the battery may explode.

Analog-to-Digital Converter Drivers

Some drivers use conversion constants for the A/D converter stored in the simple global structure **mg2adccoeff** to automatically correct readings.

```
struct mg2adccoeff {  
    int zero_offset;  
    float invgain;  
};
```



Because Dynamic C automatically creates this structure, it should not be declared in an application.

This software includes routines for determining these conversion constants from the results of measuring two known test voltages.

Function Prototypes

- **int mg2adc_read(int chan)**

Reads the specified channel **chan** of the BL1500's onboard A/D converter.

PARAMETER: **chan** ranges from 0-10 for the 11 physical A/D channels; only the first four are brought out on header H2 for actual use. The A/D converter's internal reference voltages can also be read out by addressing the following virtual channels.

chan = 11 returns $(V_{ref+} - V_{ref-})/2$

chan = 12 returns V_{ref-}

chan = 13 returns V_{ref+}

All data defaults to 12 bits unipolar mode with the most significant bit first.

This function reads an A/D converter channel in approximately 366 μ s if **AdcPioNoLock** is defined. If **AdcPioNoLock** is not defined, reading an A/D converter channel takes approximately 436 μ s. The lock prevents change in the state of the shared PIO port while the A/D converter uses the PIO port. If the PIO's other bits are only input ports, then the lock is not necessary, but an application should include following definition.

```
#define AdcPioNoLock 1
```

- **int mg2adc_set(int chan)**

Sets up the A/D converter to make readings from the specified **chan**.

PARAMETER: **chan** ranges from 0–10 for the 11 physical A/D channels. Only the first four channels are brought out on header H2 for use. Because of the A/D converters' combined read-data/setup-channel cycle of operation, this function also returns the previous reading. The A/D converter's internal reference voltages can also be read out by addressing virtual channels as shown below.

chan = 11 returns $(V_{ref+} - V_{ref-})/2$

chan = 12 returns V_{ref-}

chan = 13 returns V_{ref+}

All data defaults to 12 bits unipolar mode with the most significant bit first. This function sets/reads in approximately 258 μ s if **AdcPioNoLock** is defined. If **AdcPioNoLock** is not defined, setting up an A/D-converter channel takes approximately 292 μ s. The lock prevents changes in the state of the shared PIO port while the A/D converter is using it. If all the other PIO bits are inputs, then the lock is not necessary, but an application should include the following definition.

```
#define AdcPioNoLock 1
```

- **int mg2adc_sample(int chan, int count, int *buf, unsigned int divider)**

Samples data from the specified A/D channel **chan** at uniform intervals of time.

PARAMETERS: **chan** ranges from 0–10 for the 11 physical A/D channels. Only the first four channels are brought out on header H2 for use. Because of the A/D converters' combined read-data/setup-channel cycle of operation, this function also returns the previous reading. The A/D converter's internal reference voltages can also be read out by addressing virtual channels as shown below.

chan = 11 returns $(V_{ref+} - V_{ref-})/2$

chan = 12 returns V_{ref-}

chan = 13 returns V_{ref+}

count is the number of samples to collect.

buf points to a buffer in which to store the samples.

divider specifies the sample rate based on the equation

sample rate = $\text{sysclock} / (20 * \text{divider})$, or

divider = $\text{sysclock} * (\text{sample period} / 20)$.

All data default to 12 bits unipolar mode with the most significant bit first. The minimum value for **divider** depends on the clock speed, the number of I/O wait states, and the number of memory-wait states. For the default setting of BL1500, **divider** can be as low as 105, or about 228 μ s/conversion.

The function turns off interrupts during the entire sampling period.

RETURN VALUE: 0 if successful or -2 if the sampling rate is too fast for A/D conversion. Data are not collected if the sampling rate is too fast.



The function turns off interrupts during the entire sampling period.

- **int mg2adc_convert(unsigned int data,
 struct mg2adccoeff *cnvrsn)**

Converts raw data from an A/D conversion using the conversion constants previously stored in the **mgadccoeff** structure to which **cnvrsn** points.

RETURN VALUE: voltage equivalent of raw A/D data. Converts raw data according to the equation

$$\text{voltage} = \text{cnvrsn} \rightarrow \text{invgain} * (\text{cnvrsn} \rightarrow \text{zero_offset} - \text{data}) .$$

- **int mg2adc_writecoef(int ee_base,
 struct mg2adccoeff *cnvrsn)**

Stores the conversion constants from the **mgadccoeff** structure which **cnvrsn** points to into the simulated EEPROM of the BL1500.

PARAMETER: **ee_base** is the starting location of six consecutive bytes in which to store the calibration data.

RETURN VALUE: 0 if the data are successfully stored in the simulated EEPROM, -1 if no flash EPROM is present and therefore no simulated EEPROM is available.

- **int mg2adc_readcoef(int ee_base,
 struct mg2adaccoeff *cnvrsn)**

Reads the conversion constants from the simulated EEPROM, starting at location **ee_base**, into the **mgadccoeff** structure to which **cnvrsn** points.

RETURN VALUE: 0 if the data are successfully stored in the simulated EEPROM, -1 if no flash EPROM is present and therefore no simulated EEPROM is available.

- `int mg2adc_compute(struct mg2adccoeff *cnvrsn,
 int data1, float volt1,
 int data2, float volt2)`

Computes the **zero_offset** and **invgain** constants of the structure **mgadccoeff** from two sets of converted data and known, applied test voltages (**data1, volt1**) and (**data2, volt2**).

RETURN VALUE: 0 if the computation is successful, -1 if the data used resulted in divide by zero.

Controlling XP8300 with PIO 1 Port A

Function Prototypes

- **void mgreset_pbus()**

Initializes PIO 1 Port A to communicate with one or more XP8300 expansion boards, and resets the XP8300 boards.

An application must call this function once before accessing any XP8300.

- **int mgplc_poll_relay (int addr)**

Polls for the presence of an XP8300 board having the given board address (0 to 63).

RETURN VALUE: 1 if the board is found and 0 if the board is not found. PIO 1.

- **void mgplc_set_relay(int number, int relay,
int state)**

Turn a relay on the selected XP8300 on or off.

The board's number must be from 0 to 63.

PARAMETERS: **relay** (0–5) selects the relay on the selected XP8300.

state is 1 to turn on the relay and 0 to turn it off. PIO 1.

Nonvolatile Storage

The topmost 512 bytes of BL1500's flash EPROM are reserved as nonvolatile memory. This area can be used to store important system-state information such as A/D conversion constants so that the BL1500 can recover from power outages.

To ensure compatibility with Z-World's product line, the nonvolatile storage area simulates the EEPROM that certain Z-World controllers use for nonvolatile storage. The high-level Dynamic C functions are exactly the same for all versions of all Z-World's controllers. These drivers automatically take care of all low-level differences between physical memory devices.

- The logical addresses of the simulated EEPROM are **0x0000** to **0x0511**.
- Dynamic C BIOS reserves flash EPROM location 0 to store the operation mode and location 1 to store the baud code. The remaining locations are available for your use.

Table 5-6 gives the EEPROM constants that apply to the installed flash EPROM.

Table 5-2. Flash EPROM Simulated EEPROM Constants

Address	Definition
0x000	Startup mode: if 1, enter program mode; if 8, execute loaded program at startup.
0x001	Programming baud rate in multiples of 1200 bps. The factory default is 16, meaning 19,200 bps.

Function Prototypes

- **int ee_rd(int address)**
Reads and returns data from flash EPROM storage location address.
RETURN VALUE: -1 if a non-flash EPROM is used.
- **void ee_wr(int address, int data)**
Writes data to simulated-EEPROM storage location address.
RETURN VALUE: -1 if a non-flash EPROM is used.

- **int WriteFlash(unsigned long addr, char* buf, int num)**

Writes **num** bytes from **buf** to flash EPROM, starting at **addr**. The term **addr** is an absolute physical address.

To use this function, allocate flash EPROM data in the Dynamic C program by declaring initialized variables or arrays, or as initialized **xdata**. For **xdata**, the data name must pass directly to the following function.

```
xdata my_data { 0, 0xFF, 0x08 };
...
WriteFlash( my_data, my_buffer, my_count );
```

For normal data, the physical address of the data must pass to the following function.

```
char xxx[] = { 0, 0xFF, 0x08 };
...
WriteFlash( phy_adr(xxx), my_buffer, my_count );
```

In order for this function to work, some form of initialization has to be included when declaring the data. If the data are not declared, they will be placed in RAM instead of ROM and this function will not work.

Writing to “read-only” memory may seem contradictory. But flash EPROM, despite its name, is not really read-only memory. Writing to flash EPROM, in essence, treats the flash memory as a read/write nonvolatile memory.

RETURN VALUES:

- 0 if the operation was successful.
- 1 if no flash EPROM is present.
- 2 if a physical address is within the BIOS area (low 8K).
- 3 if a physical address is within the symbol table.
- 4 if the write times out.



Flash EPROM manufacturers rate their devices conservatively at 10,000 writes. In tests, flash EPROMs can last for 100,000 writes. When this limit is reached, the system will begin to fail, and the chip must be replaced.

Support Libraries and Sample Programs

Dynamic C provides libraries and software samples. Table 5-3 lists and describes the Dynamic C **LIB** subdirectory.

Table 5-3. Support Libraries

Library	Description
Z0232.LIB	RS-232 library for Z180 Port 0.
BL14_15.LIB	Low-level drivers for the BL1500.
MODEM232.LIB	Miscellaneous functions common to the other communication libraries.
NETWORK.LIB	RS-485 9-bit binary half-duplex support for Port 1.

Table 5-4 lists and describes sample programs in the Dynamic C **SAMPLES\NETWORK** subdirectory.

Table 5-4. Sample Programs in SAMPLES\NETWORK

Program	Description
CZ0REM.C Z0REM.C	Sample master program using Z180 Port 0 as the RS-232 communication port.
CSREMOTE.C SREMOTE.C	Sample slave program. It talks with the master running with CZ0REM.C (Z0REM.C).
RS-232.C	Simple RS-232 sample program.
RS-485.C	Simple slave program to talk with a running master.

Table 5-5 lists and defines sample programs for the Prototyping Board. These programs can be found in the Dynamic C **SAMPLES\MICROG** subdirectory.

Table 5-5. Sample Programs in SAMPLES\MICROG

Program	Description
MGSCAN1.C	Scan the I/O of the BL1500 Prototyping Board using inport and outport .
MGSCAN2.C	Scan the I/O of the BL1500 Prototyping Board using resPIODA and setPIODA .
MGSCAN3.C	Scan the I/O of the BL1500 Prototyping Board using virtual I/O.

Table 5-6 lists and describes sample programs in the Dynamic C **SAMPLES\BL14_15** subdirectory.

Table 5-6. Sample Programs in SAMPLES\MICROG

Program	Description
MG485MST.C	RS-485 master program that communicates to another BL1500 running MG485SLV.C .
MG485SLV.C	RS-485 slave program that communicates to another BL1500 running MG485MST.C .
MGCHRGERR.C	Charges a super capacitor or rechargeable battery (2.5 V–4.25 V DC) with the DS1302.
MGDEMORT.C	Demonstrates the real-time kernel (RTK) for the BL1500.
MGDSRAM.C	Writes and reads data from the RAM space of the DS1302.
MGFLASH.C	Stores data to flash EPROM “initialized data space.”
MGFLSHEE.C	Writes and reads data from simulated EEPROM of the flash EPROM.
MGLCD.C	Uses PIO 1 Port A to drive an LCD.
MGLCDCG.C	Loads and uses special characters of the LCD.
MGLCDKEY.C	Uses PIO 1 Port A and Port B to drive keypad and print to LCD.
MGPIODAC.C	Uses bit 2 of PIO 1 Port A as a simple 10-bit DAC.
MGPIOM0.C	Uses PIO 1 Port A in mode 0 (strobed-byte output).
MGPIOM1.C	Uses PIO 1 Port A in mode 1 (strobed-byte input).
MGPIOM3A.C	Uses PIO 1 Port A in mode 3 (bitwise I/O).
MGPIOM3B.C	Uses PIO 1 Port B in mode 3 (bitwise I/O).
MGPLCRLY.C	Uses PIO 1 Port A to drive XP8300 expansion board.
MGPRTPPIO.C	Uses PRT0 to time square waves generated out of the PIODA.
MGRS232.C	Uses RS-232 port on Z180 Port 0.
MGRTC.C	Reads and displays time from the real-time clock.
MGDMA232.C	Uses DMA0 to send/receive data from RS-232 Port 0.
MGSADC1.C	Reads data from BL1500’s onboard A/D converter.
MG2ADC2.C	Computes averages and standard deviation of data from BL1500’s onboard A/D converter’s channels.
MG2ADC3.C	Calibrates the onboard A/D converter channels.
MGDMAPW.C	Uses the CKA1 clock and the DMA0 as a pulse generator or crude DAC.
MG2NMI.C	Services the power-fail interrupt.
MG2WDOG.C	Monitors/triggers the watchdog timer.
MG2PIO3A.C	Uses PIO 1 A2 in mode 3 (bitwise I/O) with interrupt.
MG2PIO3B.C	Uses PIO Number 1 A2 in mode 3 (bitwise I/O) with no interrupt.



APPENDIX A: TROUBLESHOOTING

Appendix A provides procedures for troubleshooting system hardware and software. Sections include the following topics.

- Out of the Box
- Dynamic C Will Not Start
- Dynamic C Looses Serial Link
- BL1500 Repeatedly Resets
- Common Programming Errors

Out of the Box

The items listed below should have been checked before beginning development. However, rechecking may help to solve a problem occurring during development.

- Verify that the BL1500 runs in standalone mode before connecting any expansion boards or I/O devices.
- Verify that the entire host system has good, low-impedance, separate grounds for analog and digital signals. Often the BL1500 is connected between the host PC and another device. Any differences in ground potential from unit to unit can cause serious problems that are hard to diagnose.
- Do not connect analog ground to digital ground anywhere.
- Double-check the connecting cables to ensure that none are plugged backwards into the BL1500's headers.
- Verify that the host PC's COM port works by connecting a good serial device to the COM port. Remember that COM1/COM3 and COM2/COM4 share interrupts on a PC. User shells and mouse drivers, in particular, often interfere with proper COM port operation. For example, a mouse running on COM1 can preclude running Dynamic C on COM3.
- Use the Z-World power supply supplied with the Developer's Kit. If another power supply must be used, verify that it has enough capacity and filtering to support the BL1500.
- Use the Z-World cables supplied with the Developer's Kit. The most common fault of user made cables is failure to properly assert CTS at the RS-232 port of the BL1500. Without CTS being asserted, the BL1500's RS-232 port will not transmit. Assert CTS by either connecting the RTS signal of the PC's COM port or looping back the BL1500's RTS. If wiring up a DB9 connector or a RJ-12 connector to a 10-pin connector, check the connections carefully. The wires do not run pin-for-pin. Note also that telephone-company wiring does not really follow a standardized color code.
- Experiment with each peripheral device connected to the BL1500 in order to determine how it appears to the BL1500 when powered up, powered down, and/or when its connecting wiring is open or shorted.

Dynamic C Will Not Start

In most situations, when Dynamic C will not start, an error message announcing a communication failure will be displayed. The following list describes situations causing an error message and possible resolutions.

- *Wrong Baud Rate*—In rare cases, the baud rate has to be changed when using the Serial Interface Board 2 for development.
- *Wrong Communication Mode*—Both sides must be talking RS-232.
- *Wrong COM Port*—A PC generally has two serial ports COM1 and COM2. Specify the one you are using in the Dynamic C **Target Setup** menu. Use trial and error, if necessary.
- *Wrong Operating Mode*—If the BL1500's jumper is set for standalone operation, you lose communication with Dynamic C. Reconfigure the board for programming mode.
- *Wrong Memory Size*—Jumpers on headers JP1 and JP2 of the BL1500 specify the EPROM's size.
- If all else fails, connect the serial cable to the BL1500 after power up. If the PC's RS-232 port supplies a large current (most commonly on portable and industrial PCs) some RS-232 level converter ICs go into a nondestructive latch-up. Connecting the RS-232 cable after power up alleviates this problem.

Dynamic C Loses Serial Link

If the program disables interrupts for more than 50 ms, Dynamic C will lose its serial link with your program. Make sure that interrupts are not disabled for more than 50 ms.

BL1500 Repeatedly Resets

The BL1500 resets every 1.0 seconds if the watchdog timer is not “hit.” If a program does not “hit” the watchdog timer, then the program will have trouble running in standalone mode. To “hit” the watchdog, make a call to the Dynamic C library function `hitwd`.

Common Programming Errors

- Values for constants or variables out of range. Table A-1 lists accept-

Table A-1. Ranges of Dynamic C Function Types

Type	Range
int	-32,768 (-2^{15}) to +32,767 ($2^{15} - 1$)
long int	-2,147,483,648 (-2^{31}) to +2147483647 ($2^{31} - 1$)
float	1.18×10^{-38} to 3.40×10^{38}
char	0 to 255

able ranges for variables and constants.

- Mismatched “types.” For instance, the literal constant **3293** is of type **int** (16-bit integer). The literal constant **3293.0**, however, is of type **float**.
- Counting up from, or down to, one instead of zero. In software, ordinal series often begin or terminate with zero, not one.
- Confusing a function’s definition with an instance of its use in a listing.
- Not ending statements with semicolons.
- Not inserting commas as required in functions’ parameter lists.
- Leaving out an ASCII space character between characters forming a different legal—but unwanted—operator.
- Confusing similar-looking operators such as **&&** with **&**, **==** with **=**, **//** with **/**.
- Inadvertently inserting ASCII nonprinting characters into a source-code file.



*APPENDIX B: **SPECIFICATIONS***

Appendix B provides comprehensive BL1500 physical, electronic and environmental specifications.

Electrical and Mechanical Specifications

Table B-1 lists electrical, mechanical, and environmental specifications for the BL1500.

Table B-1. BL1500 General Specifications

Parameter	Specification
Board Size	3.2" × 2.3" × 0.56" (81 mm × 58 mm × 14 mm)
Operating Temperature	-40°C to 70°C, may be stored at -55°C to 85°C
Humidity	5% to 95%, noncondensing
Power	9 V DC to 12 V DC, 80 mA, linear regulator
Configurable I/O	24, 5 V TTL and CMOS compatible (I/O lines are software-selectable as either inputs or outputs)
Digital I/O	See Configurable I/O
Analog Inputs	Two 12-bit conditioned: default input range is 0 V to 10 V Two 12-bit unconditioned: 0 V to 2.5 V
Analog Outputs	No
Resistance Measurement Input	No
Processor	Z180
Clock	9.216 MHz
SRAM	128K standard, surface mounted
EPROM	Optional, supports up to 512K
Flash EPROM	Optional, supports up to 256K
EEPROM	Simulated in flash EPROM
Counters	Software-implementable
Serial Ports	One RS-232 (with CTS/RTS) and one RS-485
Serial Rate	Up to 57,600 bps
Watchdog	Yes
Time/Date Clock	Yes
Backup Battery	Connections for user-supplied battery on header H3 pin 21

BL1500 Mechanical Dimensions

Figure B-1 shows the mechanical dimensions for the BL1500.

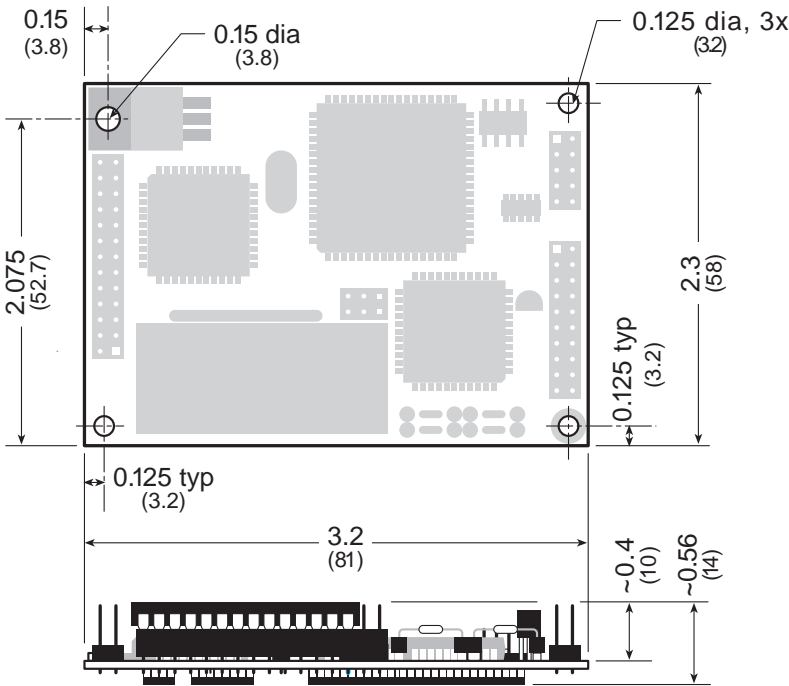


Figure B-1. BL1500 Dimensions

Prototyping Board

Figure B-2 shows the dimensions and mounting hole locations of the BL1500 Prototyping Board.

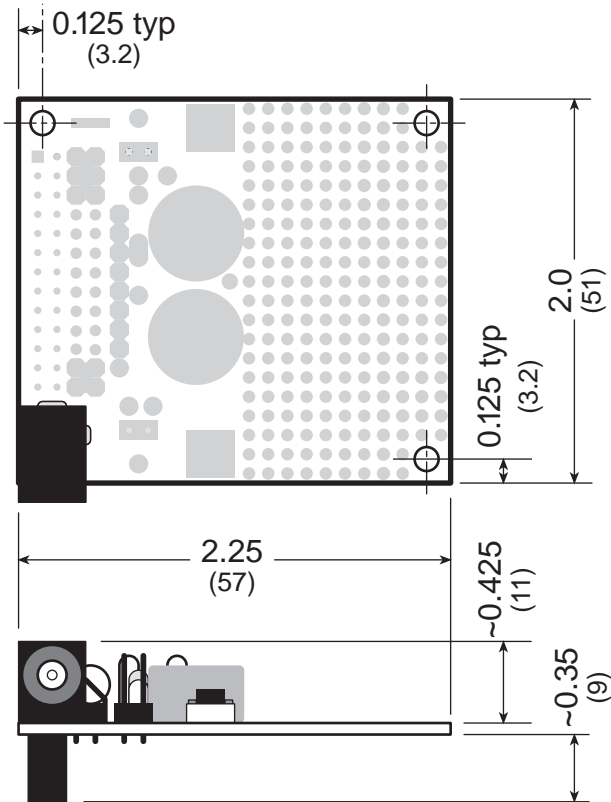


Figure B-2. BL1500 Prototyping Board Dimensions

Base Plate

Figure B-3 shows the dimensions and mounting hole locations of the BL1500 base plate supplied with the Developer's Kit. The base plate is made from 0.060" aluminum.

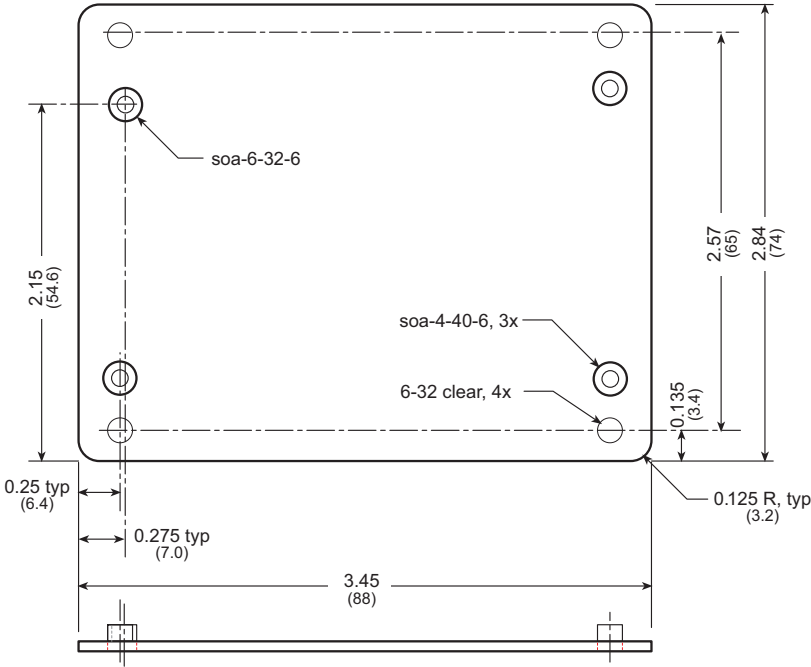


Figure B-3. BL1500 Base Plate Dimensions

Jumper and Header Specifications

Figure B-4 shows the locations of the BL1500 headers.

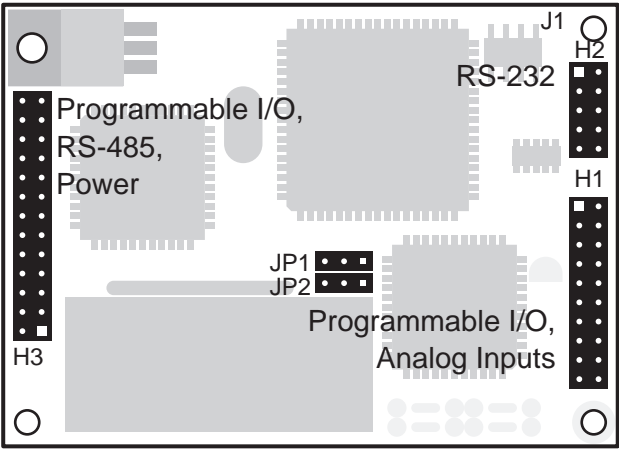


Figure B-4. BL1500 Headers

Table B-2 provides the absolute pin 1 locations for the input/output headers.

Table B-2. BL1500 Pin 1 Locations
(in inches)

Header	Location
H1	3.000, 1.250
H2	3.000, 1.950
H3	0.200, 0.600

Table B-3 describes all the headers on the BL1500.

Table B-3. BL1500 Headers

Header	Description
H1	PIO 2—Programmable I/O ports, analog inputs
H2	RS-232 and alternative programming port
H3	PIO 1—Programmable I/O ports, RS-485, power
J1	Programming/run mode and SIB2 programming port
JP1	EPROM type (flash or non-flash)
JP2	EPROM size (28-pin or 32-pin)

Header H1—PIO 2 and Analog Input Signals

Header H1 carries the I/O signals for PIO 2 (U9) and the A/D converter signals. Table B-4 lists and defines the usable I/O lines and other signals for H1.

Table B-4. PIO 2 Signals on Header H1

H1 Pin	Signal	Signal Description
1	+5 V	Regulated Power
2	P2A0	PIO 2 Port A, Data Line 0
3	P2A1	PIO 2 Port A, Data Line 1
4	P2A2	PIO 2Port A, Data Line 2
5	P2A3	PIO 2 Port A, Data Line 3
6	P2A4	PIO 2 Port A, Data Line 4
7	P2A5	PIO 2 Port A, Data Line 5
8	P2A6	PIO 2 Port A, Data Line 6
9	P2A7	PIO 2 Port A, Data Line 7
10	GROUND	Digital Ground
11	P2B4	PIO 2 Port A, Data Line 4
12	P2B5	PIO 2 Port A, Data Line 5
13	P2B6	PIO 2 Port A, Data Line 6
14	P2B7	PIO 2 Port A, Data Line 7
15	AD2	Unconditioned A/D Input
16	AD3	Unconditioned A/D Input
17	VREF	A/D Voltage Reference
18	AD1	Conditioned A/D Input
19	AGND	Analog Ground
20	AD0	Conditioned A/D Input



Pins are provided for both analog and digital ground. Make it standard practice to observe the following conventions.

- Do not mix analog and digital ground signals.
- Do not connect analog ground to digital ground external to the BL1500.
- Return sensitive, low-level analog signals to analog ground.
- Return high current, on-off signals to digital ground.

Header H2—RS-232 Port

Header H2 carries the RS-232 signals shown in Figure B-5.

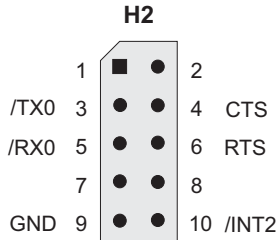


Figure B-5. Header H2 Signals



Remember to place a jumper across pins 1–2 of header J1 when using header H2 as a programming port. This jumper configuration enables the BL1500 to come up in RS-232 programming mode after power-up.

If no jumper is present and the SIB2 is not connected, the BL1500 comes up in run mode after power-up, and executes an application from EPROM. The BL1500 in run mode will not respond to attempts to develop new applications using Dynamic C.

Header H3—PIO 1, RS-485, and Power

Header H3 carries the I/O signals for PIO 1 (U2), RS-485, and power. Table B-5 lists and defines the usable I/O lines and other signals for H3.

Table B-5. PIO 1 Signals on Header H3

H3 Pin	Signal	Signal Description
1	+5 V	Regulated Power
2	P1A0	PIO 1 Port A, Data Line 0
3	P1A1	PIO 1 Port A, Data Line 1
4	P1A2	PIO 1 Port A, Data Line 2
5	P1A3	PIO 1 Port A, Data Line 3
6	P1A4	PIO 1 Port A, Data Line 4
7	P1A5	PIO 1 Port A, Data Line 5
8	P1A6	PIO 1 Port A, Data Line 6
9	P1A7	PIO 1 Port A, Data Line 7
10	GROUND	Digital Ground
11	ARDY	PIO 1 Port A Handshake Line
12	/ASTB	PIO 1 Port A Handshake Line
13	P1B7	PIO 1 Port B, Data Line 7
14	P1B6	PIO 1 Port B, Data Line 6
15	P1B5	PIO 1 Port B, Data Line 5
16	P1B4	PIO 1 Port B, Data Line 4
17	RTCCLK	Real-Time Clock Control Lines
18	RTCDAT	Real-Time Clock Data Line
19	/RESET	Reset Signal
20	GROUND	Digital Ground
21	VBAT	External Battery Input
22	GROUND	Digital Ground
23	RS-485+	RS-485+
24	RS-485-	RS-485-
25	DCIN	Unregulated Voltage Input
26	GROUND	Digital Input



Since the BL1510 and BL1520 do not have a real-time clock (RTC), PIO 2 lines P1B3 and P1B2 are available for other use.

Jumper Configurations

Table B-6 lists the jumper settings for the applicable BL1500 headers.

Table B-6. Standard BL1500 Jumper Settings

Header	Pins	Description	Factory Default
J1	1–2	Connect for RS-232 programming mode, remove for run mode	Connected
JP1	1–2	Connect for flash EPROM	Connected
	2–3	Connect for regular EPROM	
JP2	1–2	Connect for 28-pin EPROM	
	2–3	Connect for 32-pin EPROM	Connected



*APPENDIX C: **INPUT/OUTPUT MAP AND INTERRUPT VECTORS***

Memory Map

Table C-1 provides the memory map for the flash EPROM and the SRAM.

Table C-1. Memory Map

Memory Type	Low Address	High Address
Flash EPROM	00000h	3FFFFh
SRAM	80000h	FFFFFh

Input/Output Map

Other than peripherals on the Z180, the BL1500 has two byte-wide devices: PIO 1 and PIO 2. Table C-2 lists each PIO's data and control registers.

Table C-2. PIO Data and Control Registers

PIO	Name	Description	Address
PIO 1 H3	PIODA	Port A Data Register	00C0h
	PIODB	Port B Data Register	00C1h
	PIOCA	Port A Control Register	00C2h
	PIOCB	Port B Control Register	00C3h
PIO 2 H1	PIODA2	Port A Data Register	0080h
	PIODB2	Port B Data Register	0081h
	PIOCA2	Port A Control Register	0082h
	PIOCB2	Port B Control Register	0083h

The PIO and Z180 pins used for onboard housekeeping functions are listed in Table C-3.

Table C-3. Dedicated PIO Pins

Bit	Usage
PIODB.0	RTC Reset (active low)
PIODB.1	RS-485 Transmitter Enable (active high)
PIODB.2	RTC Data (Input/Output)
PIODB.3	RTC Clock
PIODB2.0	ADC Clock
PIODB2.1	ADC Data Out
PIODB2.2	ADC Data In
PIODB2.3	End of Conversion or Power Fail Output (active low)
TEND1	Toggle to Reset Watch
INT1	Watchdog Reset Status (set if watchdog times out)

Interrupt Vectors

Most interrupt vectors can be altered under program control. The addresses are relative to the start of the interrupt vector page, which is determined by the contents of the I-register. Table C-4 lists the default

Table C-4. Interrupt Vectors

Address	Signal	Description
0x00	INT1_VEC	Expansion bus attention INT1 vector
0x02	INT2_VEC	INT2 vector
0x04	PRT0_VEC	PRT Timer Channel 0
0x06	PRT1_VEC	PRT Timer Channel 1
0x08	DMA0_VEC	DMA Channel 0
0x0A	DMA1_VEC	DMA Channel 1
0x0C	CSIO_VEC	Clocked Serial I/O
0x0E	SER0_VEC	Asynchronous Serial Port Channel 0
0x10	SER1_VEC	Asynchronous Serial Port Channel 1
0x12	PIOA_VEC	PIO Channel A (through INT0)
0x14	PIOB_VEC	PIO Channel B (through INT0)
0x22	PIOA2_VEC	PIO Channel A2 (through INT0)
0x24	PIOB2_VEC	PIO Channel B2 (through INT0)

interrupt vectors set by the boot code in the Dynamic C EPROM.

In order to “vector” an interrupt to a user function in Dynamic C, a directive such as the following is used.

```
#INT_VEC 0x10 myfunction
```

This example causes the interrupt at offset 10H (Serial Port 1 of the Z180) to invoke the function **myfunction()**. The function must be declared with the **interrupt** keyword:

```
interrupt myfunction() {  
    ...  
}
```


Interrupt Priorities

Interrupt priorities are listed in Table C-5 from highest to lowest priority.

Table C-5. Interrupt Priorities

(Highest Priority)	Trap (Illegal Instruction)
	NMI (Nonmaskable Interrupt)
	INT 0 (Maskable Interrupt, Level 0, 3 modes, PIO interrupts)
	INT 1 (Maskable Interrupt, Level 1, PLCBus attention line interrupt)
	INT 2 (Maskable Interrupt, Level 2)
	PRT Timer Channel 0
	PRT Timer Channel 1
	DMA Channel 0
	DMA Channel 1
	Clocked Serial I/O
	Serial Port 0
(Lowest Priority)	Serial Port 1



*APPENDIX D: **PROTOTYPING BOARD***

Appendix D describes the BL1500 Prototyping Board.

Prototyping Board

The BL1500 Prototyping Board was designed to allow the user to experiment with the BL1500 and to prototype small circuits that can “piggyback” on the BL1500. The Prototyping Board has several pre-built subcircuits that can be tested or used as part of a custom design. An array of uncommitted pads facilitates prototyping. Power rails bring +5 V and GND to these pads.

The Prototyping Board has the following features.

- **Direct Header Connections**

Header H1 on the bottom side of the Prototyping Board connects directly to header H3 of the BL1500.

- **Array of Pads**

An array of pads for dual in-line packages (DIPs) and discrete components is provided. Pads and power rails are arranged and interconnected so that it is easy to place and connect 300-mil or 600-mil DIPs.

- **Extra Pads**

Extra pads bring out signals from header H1 on the Prototyping Board for easier soldering.

Figure D-1 illustrates the Prototyping Board.

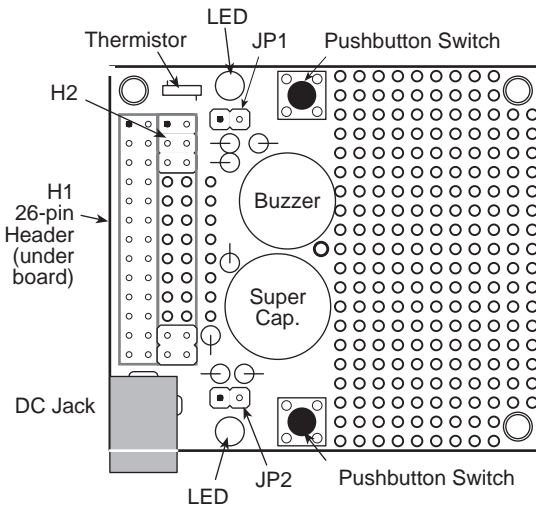


Figure D-1. BL1500 Prototyping Board

The following list notes some important points about the Prototyping Board.

- The Prototyping Board measures 2.0" × 2.25" (51 mm × 57 mm).
- The mounting holes are 0.125" in diameter. Their centers are inset 0.125" from the edges of the board.
- Signals on header H1 are identical to those on header H3 of BL1500.
- Power (9 V to 12 V DC) comes in the jack, through pin 25 of H1, then to the 5 V regulator on the BL1500, and back to the Prototyping Board on pin 1 (+5 V) of H1.
- Header H2 on the Prototyping Board is nearly identical to header H1, but most of the signal positions on H2 are pads for easy solder connections. The remaining positions on H2 are jumper pins.
- A set of nine "test points" or pads (shown in Figure D-2) make signals from the demonstration circuits available.

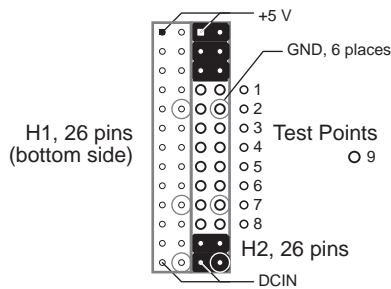


Figure D-2. Prototyping Board Signals

- Power rails bring +5 V and GND to the array of pads (see Figure D-3).

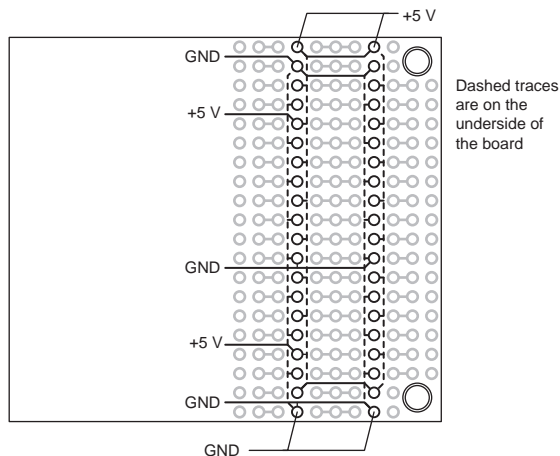


Figure D-3. Prototyping Board +5 V and GND Connections

- The array is 11×20 overall, with pads on 0.1" centers.
- Certain adjacent pads are connected, making it easy to place 300-mil (or 600-mil) DIPs and solder wires to nearby pads, rather than to the pins of the DIPs.

Installing the Prototyping Board

Connect the prototyping board to the BL1500 by pressing the header block (H1) underneath the Prototyping Board onto header H3 of the BL1500. Observe the correct orientation for the Prototyping Board: when installed, the main body of the Prototyping Board extends out away from the BL1500 (see Figure D-4). Pin 1 of H1 must connect with pin 1 of H3 on the BL1500. Otherwise, both boards will be damaged.

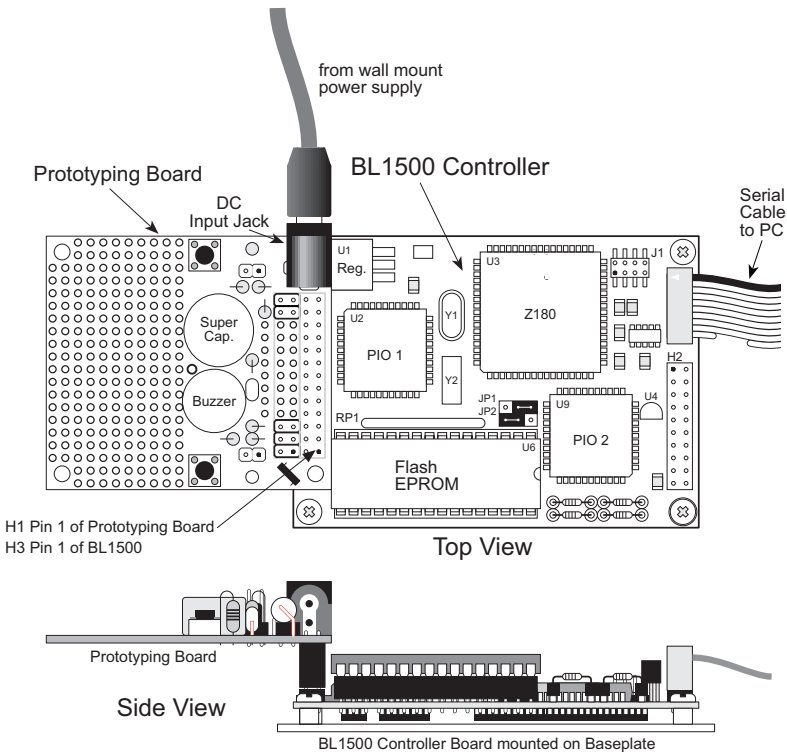


Figure D-4. Connecting the Prototyping Board to BL1500

When the Prototyping Board is installed, power for software development normally comes through the DC input jack. In the absence of a Prototyping Board (for example, when system development has been completed), power for the BL1500 comes through H3, pin 25, of the BL1500.

Sample Circuits

Several demonstration circuits are included on the Prototyping Board.

LEDs

LEDs D1 and D2 are turned on when their respective test pads (TP8, TP1) are driven with a low logic level.

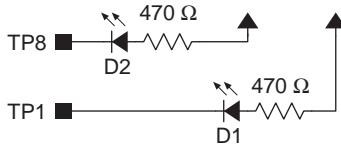


Figure D-5. Prototyping Board LEDs

Switches

Pushbutton switches SW1 and SW2 are tied to pull-up resistors. Their respective test pads (TP3, TP6) are pulled to ground when the switches are pressed.

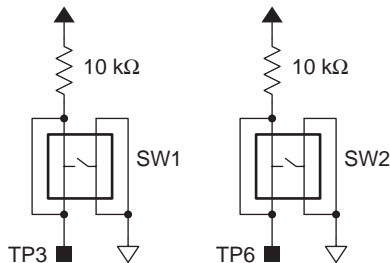


Figure D-6. Prototyping Board Switches

Headers

Headers J1 and J2 are tied to pull-up resistors. Their respective test pads (TP2, TP7) are pulled to ground when connectors are installed.

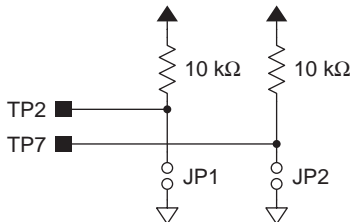


Figure D-7. Prototyping Board Headers

Buzzer

The buzzer, BZ1, is turned on when TP4 is brought to ground level.

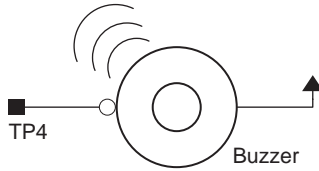


Figure D-8. Prototyping Board Buzzer

RC Filter

The RC low-pass filter consists of a $10\text{ k}\Omega$ series resistor and a $4.7\text{ }\mu\text{F}$ capacitor to ground. A variable analog voltage is developed at TP9 by driving TP5 with a pulse-width modulated (PWM) signal.

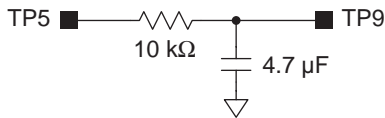


Figure D-9. Prototyping Board RC Filter

Thermistor

The Prototyping Board thermistor is not used with the BL1500.



APPENDIX E: **SERIAL INTERFACE BOARD 2**

Appendix E provides technical details and baud rate configuration data for Z-World's Serial Interface Board 2 (SIB2).

Introduction

The Serial Interface Board 2 (SIB2) is an interface adapter used to program the BL1500. The SIB2 is contained in an ABS plastic enclosure, making it rugged and reliable. The SIB2 enables the BL1500 to communicate with Dynamic C via the Z180's clocked serial I/O (CSI/O) port, freeing the BL1500's serial ports for use by the application during programming and debugging.

The SIB2's 8-pin cable plugs into the target BL1500's processor through an aperture in the backplate, and a 6-conductor RJ-12 phone cable connects the SIB2 to the host PC. The SIB2 automatically selects its baud rate to match the communication rates established by the host PC (9600, 19,200, or 57,600 bps). However, the SIB2 determines the host's communication baud rate only on the first communication after reset. To change baud rates, change the COM baud rate, reset the target BL1500 (which also resets the SIB2) by disconnecting and reconnecting the power supply, then select **Reset Target** from Dynamic C.



Chapter 2 provides detailed information on connecting the SIB2 to the BL1500.

The SIB2 receives power and resets from the target BL1500 via the 8-pin connector J1. Therefore, do not unplug the SIB2 from the target BL1500 while power is applied. To do so could damage both the BL1500 and the SIB2; additionally, the target may reset.



Never connect or disconnect the SIB2 with power applied to the controller.

The SIB2 consumes approximately 60 mA from the +5 V supply. The target-system current consumption therefore increases by this amount while the SIB2 is connected to the BL1500.

External Dimensions

Figure E-1 illustrates the external dimensions for the SIB2.

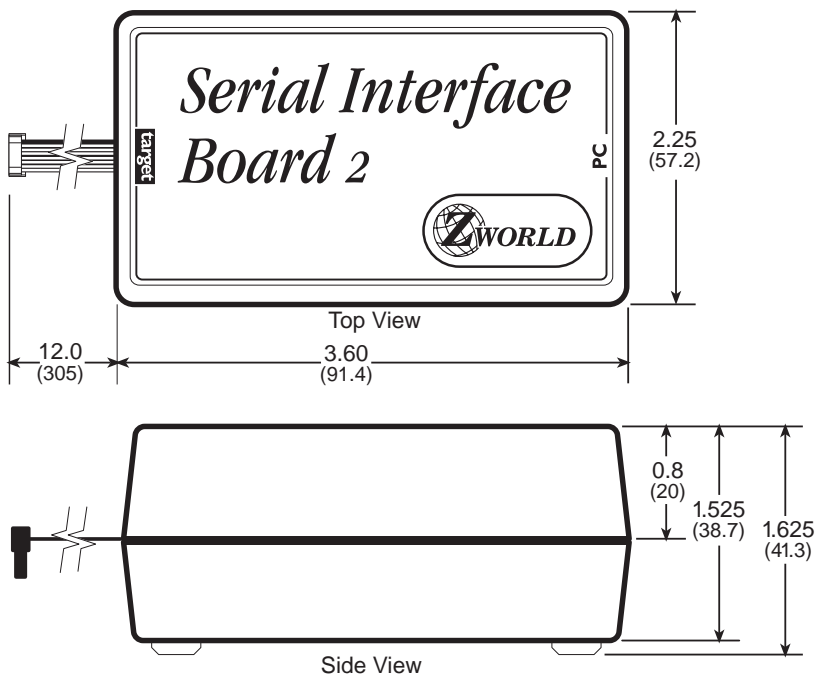


Figure E-1. SIB2 External Dimensions



*APPENDIX F: **PLCBus***

Appendix F provides the pin assignments for the PLCBus, describes the registers, and lists the software drivers.

PLCBus Overview

The PLCBus is a general-purpose expansion bus for Z-World controllers. The PLCBus is available on the BL1200, BL1600, BL1700, PK2100, and PK2200 controllers. The BL1000, BL1100, BL1300, BL1400, and BL1500 controllers support the XP8300, XP8400, XP8600, and XP8900 expansion boards using the controller’s parallel input/output port. The BL1400 and BL1500 also support the XP8200 and XP8500 expansion boards. The ZB4100’s PLCBus supports most expansion boards, except for the XP8700 and the XP8800. The SE1100 adds expansion capability to boards with or without a PLCBus interface.

Table F-1 lists Z-World’s expansion devices that are supported on the PLCBus.

Table F-1. Z-World PLCBus Expansion Devices

Device	Description
EXP-A/D12	Eight channels of 12-bit A/D converters
SE1100	Four SPDT relays for use with all Z-World controllers
XP8100 Series	32 digital inputs/outputs
XP8200	“Universal Input/Output Board” —16 universal inputs, 6 high-current digital outputs
XP8300	Two high-power SPDT and four high-power SPST relays
XP8400	Eight low-power SPST DIP relays
XP8500	11 channels of 12-bit A/D converters
XP8600	Two channels of 12-bit D/A converters
XP8700	One full-duplex asynchronous RS-232 port
XP8800	One-axis stepper motor control
XP8900	Eight channels of 12-bit D/A converters

Multiple expansion boards may be linked together and connected to a Z-World controller to form an extended system.

Figure F-1 shows the pin layout for the PLCBus connector.

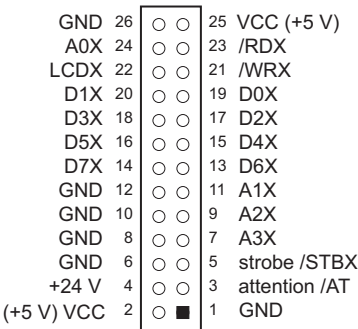


Figure F-1. PLCBus Pin Diagram

Two independent buses, the LCD bus and the PLCBus, exist on the single connector.

The LCD bus consists of the following lines.

- LCDX—positive-going strobe.
- /RDX—negative-going strobe for read.
- /WRX—negative-going strobe for write.
- A0X—address line for LCD register selection.
- D0X-D7X—bidirectional data lines (shared with expansion bus).

The LCD bus is used to connect Z-World's OP6000 series interfaces or to drive certain small liquid crystal displays directly. Figure F-2 illustrates the connection of an OP6000 interface to a controller PLCBus.

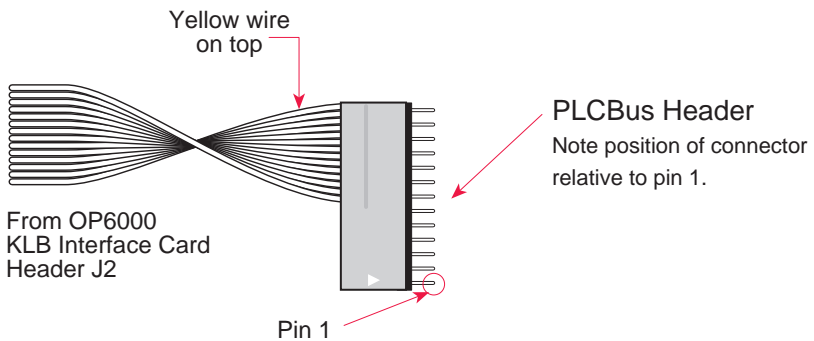


Figure F-2. OP6000 Connection to PLCBus Port

The PLCBus consists of the following lines.

- /STBX—negative-going strobe.
- A1X-A3X—three control lines for selecting bus operation.
- D0X-D3X—four bidirectional data lines used for 4-bit operations.
- D4X-D7X—four additional data lines for 8-bit operations.
- /AT—attention line (open drain) that may be pulled low by any device, causing an interrupt.

The PLCBus may be used as a 4-bit bus (D0X-D3X) or as an 8-bit bus (D0X-D7X). Whether it is used as a 4-bit bus or an 8-bit bus depends on the encoding of the address placed on the bus. Some PLCBus expansion cards require 4-bit addressing and others (such as the XP8700) require 8-bit addressing. These devices may be mixed on a single bus.

There are eight registers corresponding to the modes determined by bus lines A1X, A2X, and A3X. The registers are listed in Table F-2.

Table F-2. PLCBus Registers

Register	Address	A3	A2	A1	Meaning
BUSRD0	C0	0	0	0	Read data, one way
BUSRD1	C2	0	0	1	Read data, another way
BUSRD2	C4	0	1	0	Spare, or read data
BUSRESET	C6	0	1	1	Read this register to reset the PLCBus
BUSADR0	C8	1	0	0	First address nibble or byte
BUSADR1	CA	1	0	1	Second address nibble or byte
BUSADR2	CC	1	1	0	Third address nibble or byte
BUSWR	CE	1	1	1	Write data

Writing or reading one of these registers takes care of all the bus details. Functions are available in Z-World's software libraries to read from or write to expansion bus devices.

To communicate with a device on the expansion bus, first select a register associated with the device. Then read or write from/to the register. The register is selected by placing its address on the bus. Each device recognizes its own address and latches itself internally.

A typical device has three internal latches corresponding to the three address bytes. The first is latched when a matching BUSADR0 is detected. The second is latched when the first is latched and a matching BUSADR1 is detected. The third is latched if the first two are latched and a matching BUSADR2 is detected. If 4-bit addressing is used, then there are three 4-bit address nibbles, giving 12-bit addresses. In addition, a special register address is reserved for address expansion. This address, if ever used, would provide an additional four bits of addressing when using the 4-bit convention.

If eight data lines are used, then the addressing possibilities of the bus become much greater—more than 256 million addresses according to the conventions established for the bus.

Place an address on the bus by writing (bytes) to BUSADR0, BUSADR1 and BUSADR2 in succession. Since 4-bit and 8-bit addressing modes must coexist, the lower four bits of the first address byte (written to BUSADR0) identify addressing categories, and distinguish 4-bit and 8-bit modes from each other.

There are 16 address categories, as listed in Table F-3. An “x” indicates that the address bit may be a “1” or a “0.”

Table F-3. First-Level PLCBus Address Coding

First Byte	Mode	Addresses	Full Address Encoding
– – – – 0 0 0 0	4 bits \times 3	256	0000 xxxx xxxx
– – – – 0 0 0 1		256	0001 xxxx xxxx
– – – – 0 0 1 0		256	0010 xxxx xxxx
– – – – 0 0 1 1		256	0011 xxxx xxxx
– – – x 0 1 0 0	5 bits \times 3	2,048	x0100 xxxxx xxxxx
– – – x 0 1 0 1		2,048	x0101 xxxxx xxxxx
– – – x 0 1 1 0		2,048	x0110 xxxxx xxxxx
– – – x 0 1 1 1		2,048	x0111 xxxxx xxxxx
– – x x 1 0 0 0	6 bits \times 3	16,384	xx1000 xxxxxx xxxxxx
– – x x 1 0 0 1		16,384	xx1001 xxxxxx xxxxxx
– – x x 1 0 1 0	6 bits \times 1	4	xx1010
– – – – 1 0 1 1	4 bits \times 1	1	1011 (expansion register)
x x x x 1 1 0 0	8 bits \times 2	4,096	xxxx1100 xxxxxxxx
x x x x 1 1 0 1	8 bits \times 3	1M	xxxx1101 xxxxxxxx xxxxxxxx
x x x x 1 1 1 0	8 bits \times 1	16	xxxx1110
x x x x 1 1 1 1	8 bits \times 1	16	xxxx1111

This scheme uses less than the full addressing space. The mode notation indicates how many bus address cycles must take place and how many bits are placed on the bus during each cycle. For example, the 5×3 mode means three bus cycles with five address bits each time to yield 15-bit addresses, not 24-bit addresses, since the bus uses only the lower five bits of the three address bytes.

Z-World provides software drivers that access the PLCBus. To allow access to bus devices in a multiprocessing environment, the expansion register and the address registers are shadowed with memory locations known as *shadow registers*. The 4-byte shadow registers, which are saved at predefined memory addresses, are as follows.

SHBUS0	SHBUS0+1	SHBUS1 SHBUS0+2	SHBUS1+1 SHBUS0+3
Bus expansion	BUSADR0	BUSADR1	BUSADR2

Before the new addresses or expansion register values are output to the bus, their values are stored in the shadow registers. All interrupts that use the bus save the four shadow registers on the stack. Then, when exiting the interrupt routine, they restore the shadow registers and output the three address registers and the expansion registers to the bus. This allows an interrupt routine to access the bus without disturbing the activity of a background routine that also accesses the bus.

To work reliably, bus devices must be designed according to the following rules.

1. The device must not rely on critical timing such as a minimum delay between two successive register accesses.
2. The device must be capable of being selected and deselected without adversely affecting the internal operation of the controller.

Allocation of Devices on the Bus

4-Bit Devices

Table F-4 provides the address allocations for the registers of 4-bit devices.

Table F-4. Allocation of Registers

A1	A2	A3	Meaning
000j	000j	xxxj	digital output registers, 64 registers $64 \times 8 = 512$ 1-bit registers
000j	001j	xxxj	analog output modules, 64 registers
000j	01xj	xxxj	digital input registers, 128 registers $128 \times 4 = 512$ input bits
000j	10xj	xxxj	analog input modules, 128 registers
000j	11xj	xxxj	128 spare registers (customer)
001j	xxxj	xxxj	512 spare registers (Z-World)

j controlled by board jumper

x controlled by PAL

Digital output devices, such as relay drivers, should be addressed with three 4-bit addresses followed by a 4-bit data write to the control register. The control registers are configured as follows

bit 3	bit 2	bit 1	bit 0
A2	A1	A0	D

The three address lines determine which output bit is to be written. The output is set as either 1 or 0, according to D. If the device exists on the bus, reading the register drives bit 0 low. Otherwise bit 0 is a 1.

For digital input, each register (BUSRD0) returns four bits. The read register, BUSRD1, drives bit 0 low if the device exists on the bus.

8-Bit Devices

Z-World's XP8700 and XP8800 expansion boards use 8-bit addressing. Refer to the *XP8700 and XP8800* manual.

Expansion Bus Software

The expansion bus provides a convenient way to interface Z-World's controllers with expansion boards or other specially designed boards. The expansion bus may be accessed by using input functions. Follow the suggested protocol. The software drivers are easier to use, but are less efficient in some cases. Table F-5 lists the libraries.

Table F-5. Dynamic C PLCBus Libraries

Library Needed	Controller
DRIVERS.LIB	All controllers
EZIOTGPL.LIB	BL1000
EZIOLGPL.LIB	BL1100
EZIOMGPL.LIB	BL1400, BL1500
EZIOPLC.LIB	BL1200, BL1600, PK2100, PK2200, ZB4100
EZIOPLC2.LIB	BL1700
PBUS_TG.LIB	BL1000
PBUS_LG.LIB	BL1100, BL1300
PLC_EXP.LIB	BL1200, BL1600, PK2100, PK2200

There are 4-bit and 8-bit drivers. The 4-bit drivers employ the following calls.

- **void eioResetPlcBus()**

Resets all expansion boards on the PLCBus. When using this call, make sure there is sufficient delay between this call and the first access to an expansion board.

LIBRARY: **EZIOPLC.LIB, EZIOPLC2.LIB, EZIOMGPL.LIB.**

- **void eioPlcAdr12(unsigned addr)**

Specifies the address to be written to the PLCBus using cycles BUSADR0, BUSADR1, and BUSADR2.

PARAMETER: **addr** is broken into three nibbles, and one nibble is written in each BUSADR_x cycle.

LIBRARY: **EZIOPLC.LIB, EZIOPLC2.LIB, EZIOMGPL.LIB.**

- **void set16adr(int adr)**

Sets the current address for the PLCBus. All read and write operations access this address until a new address is set.

PARAMETER: **adr** is a 16-bit physical address. The high-order nibble contains the value for the expansion register, and the remaining three 4-bit nibbles form a 12-bit address (the first and last nibbles must be swapped).

LIBRARY: **DRIVERS.LIB.**

- **void set12adr(int adr)**

Sets the current address for the PLCBus. All read and write operations access this address until a new address is set.

PARAMETER: **adr** is a 12-bit physical address (three 4-bit nibbles) with the first and third nibbles swapped.

LIBRARY: **DRIVERS.LIB.**

- **void eioPlcAdr4(unsigned addr)**

Specifies the address to be written to the PLCBus using only cycle BUSADR2.

PARAMETER: **addr** is the nibble corresponding to BUSADR2.

LIBRARY: **EZIOPLC.LIB, EZIOPLC2.LIB, EZIOMGPL.LIB.**

- **void set4adr(int adr)**

Sets the current address for the PLCBus. All read and write operations access this address until a new address is set.

A 12-bit address may be passed to this function, but only the last four bits will be set. Call this function only if the first eight bits of the address are the same as the address in the previous call to **set12adr**.

PARAMETER: **adr** contains the last four bits (bits 8–11) of the physical address.

LIBRARY: **DRIVERS.LIB**.

- **char _eioReadD0()**

Reads the data on the PLCBus in the BUSADR0 cycle.

RETURN VALUE: the byte read on the PLCBus in the BUSADR0 cycle.

LIBRARY: **EZIOPLC.LIB, EZIOPLC2.LIB, EZIOMGPL.LIB**.

- **char _eioReadD1()**

Reads the data on the PLCBus in the BUSADR1 cycle.

RETURN VALUE: the byte read on the PLCBus in the BUSADR1 cycle.

LIBRARY: **EZIOPLC.LIB, EZIOPLC2.LIB, EZIOMGPL.LIB**.

- **char _eioReadD2()**

Reads the data on the PLCBus in the BUSADR2 cycle.

RETURN VALUE: the byte read on the PLCBus in the BUSADR2 cycle.

LIBRARY: **EZIOPLC.LIB, EZIOPLC2.LIB, EZIOMGPL.LIB**.

- **char read12data(int adr)**

Sets the current PLCBus address using the 12-bit **adr**, then reads four bits of data from the PLCBus with BUSADR0 cycle.

RETURN VALUE: PLCBus data in the lower four bits; the upper bits are undefined.

LIBRARY: **DRIVERS.LIB**.

- **char read4data(int adr)**

Sets the last four bits of the current PLCBus address using adr bits 8–11, then reads four bits of data from the bus with BUSADR0 cycle.

PARAMETER: adr bits 8–11 specifies the address to read.

RETURN VALUE: PLCBus data in the lower four bits; the upper bits are undefined.

LIBRARY: **DRIVERS.LIB.**

- **void _eioWriteWR(char ch)**

Writes information to the PLCBus during the BUSWR cycle.

PARAMETER: ch is the character to be written to the PLCBus.

LIBRARY: **EZIOPLC.LIB, EZIOPLC2.LIB, EZIOMGPL.LIB.**

- **void write12data(int adr, char dat)**

Sets the current PLCBus address, then writes four bits of data to the PLCBus.

PARAMETER: **adr** is the 12-bit address to which the PLCBus is set.

dat (bits 0–3) specifies the data to write to the PLCBus.

LIBRARY: **DRIVERS.LIB.**

- **void write4data(int address, char data)**

Sets the last four bits of the current PLCBus address, then writes four bits of data to the PLCBus.

PARAMETER: **adr** contains the last four bits of the physical address (bits 8–11).

dat (bits 0–3) specifies the data to write to the PLCBus.

LIBRARY: **DRIVERS.LIB.**

The 8-bit drivers employ the following calls.

- **void set24adr(long address)**

Sets a 24-bit address (three 8-bit nibbles) on the PLCBus. All read and write operations will access this address until a new address is set.

PARAMETER: **address** is a 24-bit physical address (for 8-bit bus) with the first and third bytes swapped (low byte most significant).

LIBRARY: **DRIVERS.LIB.**

- **void set8adr(long address)**

Sets the current address on the PLCBus. All read and write operations will access this address until a new address is set.

PARAMETER: **address** contains the last eight bits of the physical address in bits 16–23. A 24-bit address may be passed to this function, but only the last eight bits will be set. Call this function only if the first 16 bits of the address are the same as the address in the previous call to **set24adr**.

LIBRARY: **DRIVERS.LIB**.

- **int read24data0(long address)**

Sets the current PLCBus address using the 24-bit address, then reads eight bits of data from the PLCBus with a BUSRD0 cycle.

RETURN VALUE: PLCBus data in lower eight bits (upper bits 0).

LIBRARY: **DRIVERS.LIB**.

- **int read8data0(long address)**

Sets the last eight bits of the current PLCBus address using address bits 16–23, then reads eight bits of data from the PLCBus with a BUSRD0 cycle.

PARAMETER: **address** bits 16–23 are read.

RETURN VALUE: PLCBus data in lower eight bits (upper bits 0).

LIBRARY: **DRIVERS.LIB**.

- **void write24data(long address, char data)**

Sets the current PLCBus address using the 24-bit address, then writes eight bits of data to the PLCBus.

PARAMETERS: **address** is 24-bit address to write to.

data is data to write to the PLCBus.

LIBRARY: **DRIVERS.LIB**.

- **void write8data(long address, char data)**

Sets the last eight bits of the current PLCBus address using address bits 16–23, then writes eight bits of data to the PLCBus.

PARAMETERS: **address** bits 16–23 are the address of the PLCBus to write.

data is data to write to the PLCBus.

LIBRARY: **DRIVERS.LIB**.



APPENDIX G:
SIMULATED PLCBUS CONNECTION

PIO Port Connections

Expansion Boards

Expansion boards may be connected to header H3 on the BL1500. To add expansion boards, the user must either make a custom cable or use an adapter board (Z-World part number 101-0050). To assist with making the connection via a custom-made ribbon cable, Table G-1 maps the signals from the controller’s PIO to the expansion boards PLCBus header. Dynamic C’s **EZIOIMGPL.LIB** (for XP8900 Series expansion Boards) or **BL14_15.LIB** library may be used for programming.

Table G-1. PIO to PLCBus Signal Map

BL1500		Expansion Board	
H3 Pin No.	PIO Port Signal	Pin No.	PLCBus Signal
1	VCC (+5 V)	2	VCC (+5 V)
2	PA0	5	/STBX
3	PA1	19	D0X
4	PA2	20	D1X
5	PA3	17	D2X
6	PA4	18	D3X
7	PA5	11	A1X
8	PA6	9	A2X
9	PA7	7	A3X
10	GND	10	GND

The adapter board (Figure G-1) provides an easy way to add an expansion board to BL1500 series controllers. Power is supplied to the controller via the power jack and to the expansion board via a screw terminal. The expansion boards receive +12 V or +24 V from header J5 as shown when pins 1–2 on the adapter board’s header J6 are not connected. Connect pins 1–2 on the adapter board’s header J6 to power the expansion boards from DCIN, the BL1500 power supply.



Do not apply power to header J5 on the adapter board when pins 1–2 on the adapter board’s header J6 are connected.

Table G-2. PIO to LCD Signal Map

BL1400		2 × 20 LCD	
H3 Pin No.	PIO Port Signal	Pin No.	Signal
1	VCC (+5 V)	2	VDD
4	PA2	4	RS
5	PA3	6	EN
—	—	7	DB0
—	—	8	DB1
—	—	9	DB2
—	—	10	DB3
6	PA4	11	DB4
7	PA5	12	DB5
8	PA6	13	DB6
9	PA7	14	DB7
10	GND	3	VO*
26	GND	5	RD/WR
		1	VSS

* To improve contrast, connect VO to +0.3 V by adding a resistor between VO and GND instead of connecting VO to GND.

Table G-3. PIO to Keypad Signal Map

BL1400		Keypad Signal
H3 Pin No.	PIO Port Signal	
2	PA0	KeyRead 1
3	PA1	KeyRead 2
6	PA4	DriveLine 1
7	PA5	DriveLine 2
8	PA6	DriveLine 3
9	PA7	DriveLine 4
13	PB7	KeyRead 6
14	PB6	KeyRead 5
15	PB5	KeyRead 4
16	PB4	KeyRead 3

Software Drivers

Using Expansion Boards with PIO 1 Port A

A PLCBus driver is implemented using the 8-bit PIO 1 Port A (PIOA). With the BL1500, the developer is limited to 4-bit PLCBus peripherals. An attention line (/AT) is not available. The wiring connections shown in Table G-1 are used.

For multiply threaded programs, be sure to save and to restore the state of the PLCBus when entering a thread that can preempt other threads that also use the PLCBus. The function **mgsave_pbus** saves PLCBus state to the stack and **mgrestore_pbus** restores it from the stack.

- **void mgset12adr(int addr)**
Sets the current address of the PLCBus. A subsequent read or write of the PLCBus will access the expansion board with this address. The address remains in effect until a new address is set. The term **addr** is the 12-bit physical address of the PLCBus expansion board. The lowest 4-bit nibble is transmitted last (as BUSADR2). The third nibble is transmitted first (as BUSADR0).
- **void mgset12data(int addr, int data)**
Writes data to the expansion board at **addr**. Only the lowest four bits of **data** are useable (for BUSWR).
- **int mgread12data0(int addr)**
Reads data (with BUSRD0) from the expansion board at **addr**. The function result holds the data.
- **int mgread12data1(int addr)**
Reads data (with BUSRD1) from the expansion board at **addr**. The function result holds the data.
- **int mgread12data2(int addr)**
Reads data (with BUSRD2) from the expansion board at **addr**. The function result holds the data.
- **void mgwrite4data(int value)**
Writes the low 4 bits of **value** (with BUSWR) to an expansion board. This function assumes that the expansion board's address has been placed on the PLCBus (with **mgset12adr**).
- **void mgreset_pbus()**
Initializes PIO Port A to communicate with expansion boards. The function also resets all expansion boards.

- **int mgplc_poll_node(int addr)**

Polls for the presence of an expansion board with the given board address. The function returns 1 if the board is found and 0 if the board is not found.

- **void mgsave_pbus()**

Saves the current state of the PLCBus to the stack. This function should only be called in tandem with **mgrestore_pbus**. Otherwise, the stack will become unbalanced.

- **void mgrestore_pbus()**

Restores the current state of the PLCBus from the stack. This function should only be called in tandem with **mgsave_pbus**. Otherwise, the stack will become unbalanced.

- **void mgplc_set_relay(int number, int relay, int state)**

Turns a relay on an expansion board on or off. The relay board must be a Z-World XP8300 or XP8400 expansion board and its **number** must be from 0 to 63. The term **relay** selects the relay on the selected board (0–5 for XP8300 boards and 0–7 for XP8400 boards. The term **state** is 1 to turn on the relay board and 0 to turn it off.



Refer to the *XP8300, XP8400 and SE1100 User's Manual* for details regarding devices and device numbering schemes.

- **int mgplcrly_board(int number)**

Computes the physical address of a relay board from its board **number**. The number must be from 0 to 63. (Board number 0 corresponds to address 0x000; board number 63 corresponds to address 0x11F.) The return value has the third and the first nibbles interchanged.



Refer to the *XP8300, XP8400 and SE1100 User's Manual* for details regarding devices and device numbering schemes.

- **int mgplcuio_board(int number)**

Computes the physical address of an XP8200 expansion board from its board **number**. The number must be from 0 to 15. (Board number 0 corresponds to address 0x040. Board number 15 corresponds to address 0x04F.) The return value has the third and the first nibbles interchanged.



Refer to the *XP8100 and XP8200 User's Manual* for details regarding devices and device numbering schemes.

- **int mgplc_dac_board(int number)**

Computes the physical address of an XP8600 or XP8900 expansion board from its board **number**. The number must be from 0 to 63. (Board number 0 corresponds to address 0x020; board number 63 corresponds to address 0x13F.) The return value has the third and the first nibbles interchanged.



Refer to the *XP8600 and XP8900 User's Manual* for details regarding devices and device numbering schemes.

- **void mginit_dac()**

Initializes an XP8600 or XP8900 expansion board on the PLCBus. This function assumes that the board's address has been placed on the bus (with **mgset12adr**).

- **void mgwrite_dac1(int value)**

Writes the 12-bit integer **value** to Register A of DAC 1 of an XP8600 or XP8900 expansion board on the PLCBus. This function assumes that the board's address has been placed on the bus (with **mgset12adr**). The an XP8600 or XP8900 expansion board does not produce a new conversion value until a call to **mg latch_dac1** is executed.

- **void mg latch_dac1()**

Moves Register A data to Register B of DAC 1 of an XP8600 or XP8900 expansion board on the PLCBus. The actual DAC 1 output is converted from Register B. This function assumes that the board's address has been placed on the bus (with **mgset12adr**). Be sure that Register A contains valid data. See **mgwrite_dac1** above.

- **void mgset_dac1(int value)**

Writes a 12-bit integer **value** to Register A, then moves the data from Register A to Register B of DAC 1 of a selected XP8600 or XP8900 expansion board. This function assumes that the board's address has been placed on the bus (with **mgset12adr**). It combines the effect of **mgwrite_dac1** and **mg latch_dac1**.

- **void mgwrite_dac2(int value)**

Writes the 12-bit integer **value** to Register A of DAC 2 of an XP8600 or XP8900 expansion board on the PLCBus. This function assumes that the board's address has been placed on the bus (with **mgset12adr**). The XP8600 or XP8900 expansion board does not produce a new conversion value until a call to **mg latch_dac2** is executed.

- **void mglatch_dac2()**

Moves Register A data to Register B of DAC 2 of an XP8600 or XP8900 expansion board on the PLCBus. The actual DAC 2 output is converted from Register B. This function assumes that the board's address has been placed on the bus (with **mgset12adr**). Be sure that Register A contains valid data. See **mgwrite_dac2** above.

- **void mgset_dac2(int value)**

Writes a 12-bit integer **value** to Register A, then moves the data from Register A to Register B of DAC 2 of a selected XP8600 or XP8900 expansion board. This function assumes that the board's address has been placed on the bus (with **mgset12adr**). It combines the effect of **mgwrite_dac2** and **mglatch_dac2**.

Using an LCD with PIO Port A

A 4-bit LCD (liquid crystal display) driver is implemented through six bits of PIO 1 Port A.

The LCD drivers are compatible with the keypad drivers in the following section. That is, both an LCD and a keypad can be driven with this software and a BL1500.

- **void lc_char(byte data)**

Writes a character to the LCD.

- **void lc_ctrl(byte cmd)**

Writes a control command to the LCD.

- **void lc_init()**

Initialize the LCD and accessory variables. The LCD uses PIO Port A.

- **void lc_cgram(void *ptr)**

Loads up to eight special characters to the character generator of the LCD from the byte array ***p**. The first byte in the array is the number of bytes to store (at 8 bytes per character), with a maximum value of 64 for 8 characters. The character codes for the special characters are 0, 1, 2, 3, 4, 5, 6, and 7.

- **void lc_printf(char* format, ...)**

This function works like **printf**, but for the LCD. The escape sequences shown in Table G-4 are also implemented.

The escape character code is **0x1B**.

Table G-4. LCD printf Escape Sequences

Command	Result
<ESC> l	Turn cursor on
<ESC> o	Turn cursor off
<ESC> c	Erase from cursor to end of line
<ESC> b	Enable cursor blinking
<ESC> n	Disable cursor blinking
<ESC> e	Erase display and home cursor
<ESC> p n mm	Position cursor at line n, column mm

Using a Keypad with PIO Ports A and B

A keypad driver is implemented using PIO 1 Ports A and B of the BL1500.

The keys are scanned by forcing the driver lines low, one at a time, and sensing the key read lines. A low level on a key read line indicates a key press. Call the function `lc_keyscan` periodically to scan the keypad.

“Debouncing” is done by making sure a key is pressed for `DebounceCount` consecutive calls to `lc_keyscan`. The debouncing number can be changed by redefining `DebounceCount`:

```
#define DebounceCount nn
```

If not redefined, `DebounceCount` defaults to 20. If `lc_keyscan` is called every 25 ms and `DebounceCount` is 20, then a key has to be pressed for $20 \times 25 \text{ ms} = 500 \text{ ms}$ to be valid.

The keypad drivers are compatible with the preceding LCD drivers. That is, both an LCD and a keypad can be driven with this software on a BL1500.

- **lc_kxinit()**

Initializes the keypad driver and accessory variables. Define `KEY4x6` somewhere at the start of the code if using a 4×6 keypad.

```
#define KEY4x6
```

Otherwise, the driver defaults to a 2×6 keypad.

- **int lc_kxget(int mode)**

Obtains the key value from the FIFO keypad buffer. If `mode = 0`, the key value is removed from the buffer. Otherwise, the key value is left in the buffer. In either case, the function returns the key value, or -1 if the keypad buffer is empty.

- **void lc_keyscan()**

Scans the 4×6 or 2×6 keypad. A valid key has to be persistent for **DebounceCount** calls to **lc_keyscan**. The function puts valid key presses into the keypad FIFO buffer. The software will access these key presses using **lc_kxget**.



For more information or assistance, call a Z-World Technical Support Representative at (530) 757-3737.



*APPENDIX H: **POWER MANAGEMENT***

Appendix H provides detailed information on power systems and sources. Sections include the following topics.

- Direct Current Input
- Power Regulator
- Power Failure

Direct Current Input

During software development, power (9 V to 12 V DC) comes through the DC input jack of the Prototyping Board. In the absence of this board (for example, when system development has been completed) power for the BL1500 must be applied to pin 25 on header H3.

Power Regulator

The BL1500 has an onboard +5 V linear regulator that accepts an input voltage of 9 V to 12 V DC. The BL1500 itself draws approximately 80 mA. The regulator has some excess capacity to power expansion boards or external loads. The regulator package is a TO-220 rated for 1.0 W at an ambient temperature of 70°C without additional heat sinking.

Heat sinking can be enhanced by mounting the BL1500 so that the regulator makes contact with a mounting stud and a metal chassis or plate. Forced-air cooling, if available, will dissipate additional power.

Maximum Power Dissipation

The maximum allowable power dissipation of the onboard 5 V regulator at any ambient temperature is a function of the maximum junction temperature at which the regulator is operating. If the maximum power dissipation is exceeded, the regulator's junction temperature will rise above T_{JMAX} and the electrical specifications will not apply. If the die temperature rises above 150°C, the regulator will go into thermal shutdown. The LM340 used by the BL1500 has a maximum junction temperature of 125°C.

The maximum power dissipation can be computed as follows.

$$P_{MAX} = \frac{(T_{JMAX} - T_A)}{\theta_{TOTAL}} \quad (H-1)$$

where

P_{MAX} is the maximum power dissipation in watts

T_{JMAX} is the maximum junction temperature in degrees Celsius

T_A is the ambient temperature in degrees Celsius

θ_{TOTAL} is the thermal resistance from the junction to the ambient air, °C/W.

Thus,

$$\begin{aligned} P_{MAX} &= \frac{(125^{\circ}\text{C} - 70^{\circ}\text{C})}{54^{\circ}\text{C/W}} \\ &= 1.019 \text{ W at } 70^{\circ}\text{C}. \end{aligned}$$

In terms of the input voltage and current consumption of the board,

$$P_{\text{MAX}} = (V_{\text{IN}} - 5) \times I \quad (\text{H-2})$$

where

V_{IN} is the input DC voltage to the board (9 V to 12 V), and

I is the current consumption of the board.

Heat Dissipation with the BL1400 Base Plate

The junction-to-case thermal resistance, θ_{JC} , of the LM340 is 4°C/W. The thermal resistance (θ_{CS}) from the case to the top surface of the printed circuit board (PCB) is about 1°C/W.

From the top surface to the bottom surface, the three heat paths are the plating on the two 0.150-inch-diameter holes and through the printed circuit board. Assuming a solder lamination of 0.001", the heat resistance across one hole is approximated as follows.

$$\begin{aligned} \theta_{\text{HOLE}} &= \frac{0.06}{(2.54 \times 0.15 \times 0.001 \times \pi \times 3.46)} \\ &\approx 14.5^\circ\text{C/W}. \end{aligned}$$

The thermal resistance across the 0.6" × 0.4" printed circuit board is approximated as follows.

$$\begin{aligned} \theta_{\text{PCB}} &= \frac{0.06}{(2.54 \times 0.6 \times 0.4 \times 0.0016)} \\ &\approx 62^\circ\text{C/W}. \end{aligned}$$

The contact thermal resistance from the bottom of the printed circuit board to the 6-32 PEM nut is approximately 1°C/W. The thermal resistance across a 3/16" long aluminum PEM is approximately

$$\begin{aligned} \theta_{\text{PEM}} &= \frac{0.1875}{(2.54 \times 0.016 \times 2.595)} \\ &\approx 1.8^\circ\text{C/W}. \end{aligned}$$

The base plate has a thermal resistance of approximately 7.5°C/W. Therefore,

$$\begin{aligned} \theta_{\text{TOTAL}} &= \theta_{\text{JC}} + \theta_{\text{CS}} + (\theta_{\text{HOLE}} \parallel \theta_{\text{HOLE}} \parallel \theta_{\text{PCB}}) + \theta_{\text{SP}} + \theta_{\text{PEM}} + \theta_{\text{BASE}} \\ &= 4 + 1 + (14.5 \parallel 14.5 \parallel 62) + 1 + 1.8 + 7.5 \\ &= 4 + 1 + 6.5 + 1 + 1.8 + 7.5 \\ &= 22^\circ\text{C/W}. \end{aligned}$$

At an ambient temperature of 50°C, the maximum power dissipation is

$$P_{\text{MAX}} = (125 - 50) / 22 \cong 3.57 \text{ W.}$$

With V_{IN} equal to 12 V, the maximum current draw is

$$I = 3.57 / (12 - 5) \cong 510 \text{ mA.}$$

Heat Dissipation without the Base Plate

If the BL1500 is to be mounted on a heat-conducting surface, Z-World recommends the following mounting scheme. Use a 6-32 steel screw to hold the regulator to a ¼" 6-32 aluminum standoff mounted on a large heat sink. A conservative estimate of the thermal resistance is as follows.

The thermal resistance across a ¼-6-32 aluminum standoff of ¼" height is

$$\begin{aligned}\theta_{\text{AL}} &= \frac{0.25}{2.54 \times 0.035 \times 2.595} \\ &= 1^\circ\text{C/W.}\end{aligned}$$

Assuming a basis of 5 °C/W, the total thermal resistance becomes

$$\begin{aligned}\theta_{\text{TOTAL2}} &= \theta_{\text{JC}} + \theta_{\text{CS}} + (\theta_{\text{HOLE}} \parallel \theta_{\text{HOLE}} \parallel \theta_{\text{PCB}}) + \theta_{\text{SP}} + \theta_{\text{PEM}} + \theta_{\text{BASE}} \\ &= 4 + 1 + (14.5 \parallel 14.5 \parallel 62) + 1 + 1 + 5 \\ &= 4 + 1 + 6.5 + 1 + 5 \\ &= 17.5^\circ\text{C/W.}\end{aligned}$$

At an ambient temperature of 50°C, the maximum power dissipation is

$$P_{\text{MAX}} = (125 - 50) / 17.5 = 4.28 \text{ W.}$$

With V_{IN} equal to 12 V, the maximum current draw is

$$I = 4.28 / (12 - 5) = 611 \text{ mA.}$$

Power Failure

Figure H-1 shows the power-failure detection circuitry of the BL1500.

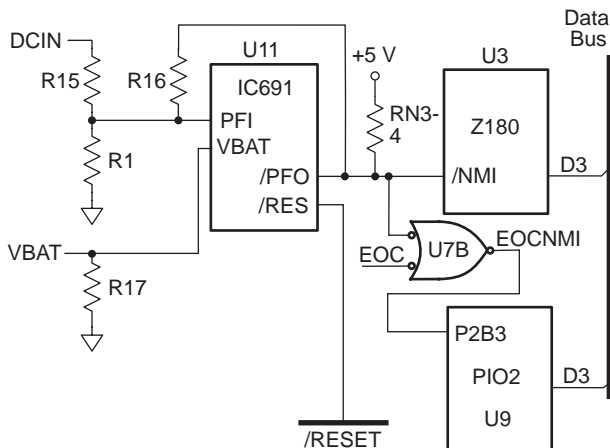


Figure H-1. Power Failure Circuitry

Power Failure Sequence of Events

The following events occur: as the input power fails.

1. The power-management integrated circuit triggers a power-failure **/NMI** (nonmaskable interrupt) when the unregulated direct current input voltage falls below approximately 7.9 V (as determined by the voltage divider R1 and R15). This provides a “holdup” period (t_H) during which the power-fail routine may store important state data.
At some point, the raw input voltage level will not exceed the regulated voltage level required by the regulator’s dropout voltage. At that point, the regulated output begins to drop.
2. The power management integrated circuit triggers a system reset (**/RESET**) when the regulated +5 V supply falls below approximately 4.65 V. The power management chip forces the chip-enable line of the SRAM high (standby mode), which prevents the system from writing to the RAM.
3. If an external backup battery is installed, the watchdog integrated circuit preserves the RAM’s data by switching to battery power when the regulated voltage falls below the battery’s voltage (2.5 V to 4.25 V DC).
4. The power management integrated keeps **/RESET** enabled until the regulated voltage drops below 1 V. The power management integrated ceases operating below 1 V and the portion of the circuit that is not backed by battery has already ceased functioning.

Figure H-2 illustrates the power-failure sequence.

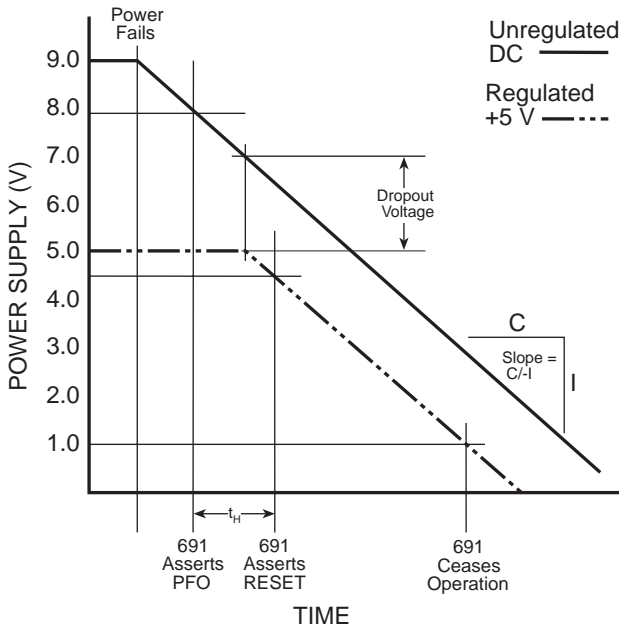


Figure H-2. Power-Failure Sequence

Multiple Power-Line Fluctuations

The power fail detection system can fail when multiple power fluctuations rapidly follow each other, a common occurrence in the real world. If the BL1500's Z180 microprocessor receives multiple **/NMI**s, it overwrites an internal register, making a correct return from the first **/NMI** impossible. Depending on the number of fluctuations of the raw DC input (and hence, the number of stacked **/NMI**s), the microprocessor's stack could possibly overflow, corrupting your program's code or data.

When the Z180 senses an **/NMI**, it saves the program counter (**PC**) on its processor stack, copies the maskable interrupt flag IEF1 to IEF2, and then zeroes IEF1. The Z180 restores IEF2's saved state information when it executes a **RETN** (Return from Nonmaskable Interrupt) instruction.

Recommended Power-Failure Routine

Z-World recommends the following routines to handle an **/NMI**. The routines monitor the state of the **/PFO** line (via U7B, PIO 2, and the data bus) to determine if the brownout condition is continuing or if the power has returned to normal levels. If this routine is used, you will never have to worry about multiple power-failure **/NMIs** because the routine never returns from the first **/NMI** unless the power returns.

```
main() {
    ...
}

...

char dummy[24];           // reserve dummy stack
                           // for /NMI processing

...

#define NMI_BIT 3         // routine will test data
                           // bit 3 to determine
                           // state of /NMI line

#JUMP_VEC NMI_VEC myint

#asm
myint::
    ld    sp,dummy+24      ; force stack pointer
                           ; to top of "dummy"
                           ; array to prevent
                           ; overwriting of code
                           ; or data

    do whatever service, within allowable execution time
loop:
    call hitwd             ; make sure no
                           ; watchdog reset

                           ; during brownout
    ld    bc,NMI           ; load the read-NMI
                           ; register to be
    in    a,(c)            ; read the read-NMI
                           ; register to /PFO
    bit   NMI_BIT, a       ; check /PFO status
    jr    z,loop           ; wait until brownout
                           ; condition clears

timeout:
                           ; then... a tight loop
                           ; to force a watchdog
                           ; timeout
    jp    timeout          ; which will reset the Z180
#endasm
```

If the DC input voltage continues to decrease, the controller powers down. The routine calls `hitwd` to make sure that watchdog does not timeout and thereby reset the processor. The controller can continue to run at low voltage (and might not be able to detect the low-voltage condition) because the Z180's `/NMI` input needs to see a high-to-low transition edge.

A situation similar to a brownout will occur if the power supply is overloaded. In such a case, the raw voltage supplied to the Z180 may dip below 7.9 V when a high-current load turns on. In response, the interrupt routine performs a shutdown that turns off the high-current load, clearing the problem. However, if the cause of the overload persists, the system “hunts,” alternately overloading and then resetting. To correct this situation, obtain a larger, “stiffer” power supply.

Holdup Time

Z-World cannot predict how much time is available to save important data. The ratio of a DC power supply's output capacitor value to the circuit's current draw determines the actual duration of the holdup time interval, t_H .

A few milliseconds of computing time remain until the regulated +5 V supply falls below approximately 4.65 V, even if the power cuts off abruptly.

The amount of time depends on the size of the power supply capacitors. The standard wall power supply provides about 10 ms. If the power cable is abruptly removed from the BL1500, only the capacitors on the board are available, reducing computing time to a few hundred microseconds. These times can vary considerably depending on system configuration and loads on the 5 V or 9 V power supplies.

The interval between the power-failure detection and entry to the power-failure interrupt routine is approximately 6 μ s or less.

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