PLCBus™

The PLCBus™ is a Z-World concept that allows you to extend your control system by the addition of expansion boards. Rather than buy controllers with many I/O lines, you can get smaller controllers to which you add lines, according to your needs. Z-World's PLCBus concept also allows you to build your own expansion boards, following a few guidelines.

Z-World offers these expansion boards:

Series	Name	Description
XP8100	IO32	32 protected digital I/O lines, configurable as inputs or outputs in groups of eight. 3.525×2.835 (89.5×72 mm)
XP8200	UIO	Six high-current outputs and 16 universal inputs, which can be used as digital inputs (with single or dual thresholds) or analog inputs. 3.525×2.835 (89.5×72 mm)
XP8300	RELAY6	Six SPDT 10A relays. 3.525×2.835 (89.5×72 mm)
XP8400	RELAY8	Eight DIP relays, each SPST, 500 mA, normally open. 2.2×2.835 (55.9×72 mm)
XP8500	ADC4	Four 12-bit ADC channels with signal conditioning, seven channels without. 3.525×2.835 (89.5×72 mm)
*	A/D12	Eight configurable ADC channels. Selectable gain, differential or single-ended. 3.525×2.835 (89.5×72 mm)
XP8600	DAC2	Two DAC channels. 3.525×2.835 (89.5×72 mm)
XP8700	RS232	Single RS232 serial communication channel. 2.2×2.835 (55.9×72 mm)
XP8800	SMC	Single-axis stepper motor controller with quadrature decoder and high-speed counter. 4.0×2.835 (101.6×72 mm)
XP8900	DAC8	Four or eight DAC channels. 4.0×2.835 (101.6×72 mm)

The PLCBus, physically, is a set of one or more 26-wire ribbon cables with which you connect a series of expansion boards to a controller. When you have several boards connected, the cables act as a "flexible backplane." The limits to the number of boards on a bus are power and addressability. You can address up to 64 relay boards *and* up to 64 A/D12 boards *and* up to 32 UIO boards, and so forth, on a single bus. TTL loading limits the number of boards on a single bus.

You can also build networks of controllers, each having expansion boards.

All PLCBus expansion boards are 72 mm in width and fit in DIN rail cards. Z-World expansion cards can also be installed, with standoffs, on almost any flat surface that accepts screws. Generally, mounting holes are 1/8″ (0.125″) in from the edge of a board, with a diameter of 0.187.″

A RELAY6, a UIO board and an ADC4 board, when properly cabled to a PK2200, would look something like this:
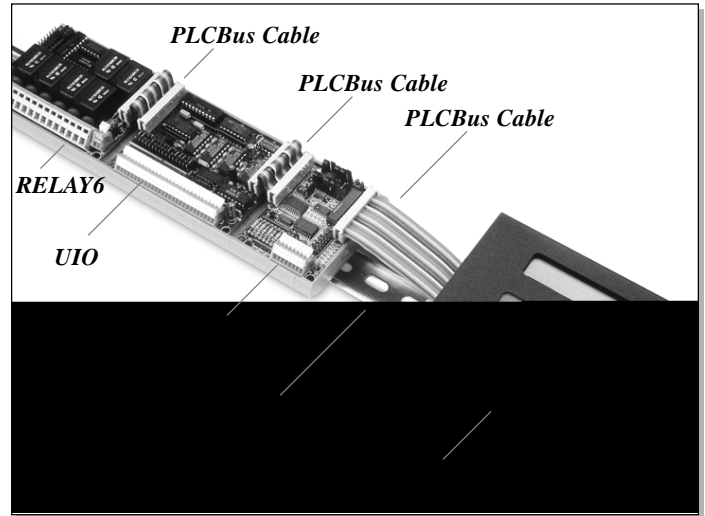
Most Z-World controllers support the PLCBus, although some require special connectors. (Some controllers have limited software support. Some do not have an actual PLCBus port.)

Z-World software usually hides most of the detail of operating a PLCBus board. In practice, you need only make "plug and play" physical connections, and make a few function calls in your software.

The Concept

PLCBus devices connect with 26-wire ribbon cable (included with the board) with the following pin assignments:

The PLCBus core signals consists of

/AT	Attention line (open drain). May be pulled low by any PLCBus device, causing an interrupt.
/STBX	Negative going strobe.
A1X, A2X, A3X	Three mode lines, for selecting bus operation.
D0X–D7X	Bidirectional data lines.
+V	PLCBus power. Either 24VDC (for 24V boards) or 12VDC (for 12V boards).
VCC, GND	Normal regulated +5V and ground.

References

Please refer to

- *Zilog: Z180 MPU User's Manual*
- *Zilog: Z180 Serial Communication Controllers*
- *Zilog: Z80 Microprocessor Family User's Manual*
- *Z-World: Dynamic C Data Sheet*
- *Z-World: PCL-AK Tech Note (101)*
- *Signetics: SCC2691 (UART) Data Sheet*

Contents

	A1X
BUSRD0	0 0 0
	0 1
	1 0
	1 1
BUSADR0	1 0 0
	0 1
	1 0
	1 1

BUSADR1

2

Bus Topology

A device on the PLCBus generally has one or more *ports* (control registers or data registers). For example, Z-World relay boards each have one 4-bit control register. RS232 (XP8700) boards each have one 8-bit control register and one 8-bit data register.

Thus, a PLCBus device has one or more port addresses. All addresses on a single bus must be unique. Each device on the bus recognizes its own set of addresses (by PAL encoding, jumper wiring and other forms of logic). Each board responds only when it is being addressed.

Any PLCBus device may have an *address expansion* register. This is a register that can be used to extend the address space of the device. No Z-World expansion card has an expansion register at present.

Addressing modes (discussed later) and address expansion registers allow you (theoretically) to build a PLCBus with millions of devices or perhaps a few devices with millions of addresses. Z-World expansion boards typically have one or two addresses.

Communicating with Devices on the Bus

To operate a PLCBus device, your program (running in your controller) will read from it or write to it. The steps involved are as follows:

0   Initially, reset the devices on the bus.

1   Select a board—or a board register—by placing its address on the bus.

2   If the board has an address expansion register, you might need to set its value.

3   Send data to the device or read data from the device.

How it is done

There are 8 memory-mapped registers that correspond to the 8 bus cycles determined by the 3 bus lines A1X, A2X, and A3X. Their specific addresses depend on the controller you are using.

Register	-	Meaning
		Read data, cycle 0
BUSRD1	0	Read data, cycle 1
BUSRD2	0	Read data, cycle 2
BUSRESET	0	Reading this register resets the entire PLCBus.
		Bus address, cycle 0
BUSADR1	1	Bus address, cycle 1
BUSADR2	1	Bus address, cycle 2
BUSWR	1	Write data

To place an address on the bus, write 1, 2, or 3 bytes in succession to BUSADR0, , BUSADR2 respectively. Whether you write 1, , or 3 bytes depends on addressing modes described below. The addressing modes allow up to 24-bit addresses, with -bit addresses being most typical. The address expansion register can extend this space.

You can read up to 24 bits using the BUSRD0, BUSRD1, and BUSRD2 cycles. You can write up to eight bits using BUSWR.

Primitive functions are available in Z-World's software libraries to carry out these bus cycles. Higher level functions are also available. They take care of the details for you.

Bus Addresses

To allow you to use an arbitrary combination of bus devices, in anticipation of future products and third-party products, Z-World has established a two-level addressing scheme. The first level in the scheme specifies how addresses are encoded when placed on the bus. The second level in the scheme specifies the actual addresses assigned to Z-World devices.

First level: placing addresses on the bus

You place an address on the bus by writing to BUSADR0, BUSADR1 and BUSADR2 in succession. Doing so places address bits on the data lines (D0X–D7X) and modifies the mode lines (A3X–A1X). A PLCBus devices must respond by comparing the address bits with its own address.

The lower four bits of the first address byte identify *address categories*. There are 16 address categories, given in the table below. The symbol "–" indicates an unused bit. An "x" indicates the address bit may be a 1 or a 0. Each PLCBus device recognizes its own category and responds to that and no other. The 'x' bits are further encoded by the second level of the addressing scheme, as you will see later.

Not all these categories are in use.

Z-World software also maintains "logical" address spaces that map to physical address spaces. Generally, the logical space simply numbers the boards sequentially.

Abbreviated Addresses

Assume you have just placed a full PLCBus address on the bus and wish to place another address on the bus. If the first two bytes of the next address are the same as for the previous address, it is sufficient to write BUSADR2 only.

Expansion Register

Addressing the expansion register is a special case: the encoding scheme uses one byte which has a fixed value (0xB). When you write to this address, all devices which have an expansion register respond by latching the data from the next BUSWR.

The following sample code writes 3 to expansion registers:

```
ld   a,0xB        ;0xB addresses ALL exp regs
out0 (BUSADR0),a
ld   a,3          ;All expansion registers get 3
out0 (BUSWR),a
...
```

At present, no Z-World device has an expansion register. If you design a PLCBus expansion card, the use of an expansion register is up to you.

Second Level: Physical Device Addresses

The second level of the addressing scheme specifies what addresses a PLCBus device can occupy. This applies primarily to PLCBus devices manufactured by Z-World.

Each Z-World expansion card has a unique second-level address based on PAL coding and jumper wiring. The second-level address scheme is described, for each product, in the section that describes the product.

For PLCBus devices that have PAL encodings, you will have to order boards with the specific PAL in the quantity you need, if you want to have more than one such board on a PLCBus.

	First byte	Mode	Addresses	Full address encoding
1	– – – – 0 0 0 0	4 bits x 3	256	0000 xxxx xxxx
2	– – – – 0 0 0 1		256	0001 xxxx xxxx
3	– – – – 0 0 1 0		256	0010 xxxx xxxx
4	– – – – 0 0 1 1		256	0011 xxxx xxxx
5	– – – x 0 1 0 0	5 bits x 3	2,048	x0100 xxxxx xxxxx
7	– – – x 0 1 0 1		2,048	x0101 xxxxx xxxxx
7	– – – x 0 1 1 0		2,048	x0110 xxxxx xxxxx
8	– – – x 0 1 1 1		2,048	x0111 xxxxx xxxxx
9	– – x x 1 0 0 0	6 bits x 3	16,384	xx1000 xxxxxx xxxxxx
10	– – x x 1 0 0 1		16,384	xx1001 xxxxxx xxxxxx
11	– – x x 1 0 1 0	6 bits x 1	4	xx1010
12	– – – – 1 0 1 1	4 bits x 1	1	1011 (expansion reg.)
13	x x x x 1 1 0 0	8 bits x 2	4,096	xxxx1100 xxxxxxxx
14	x x x x 1 1 0 1	8 bits x 3	1 Meg	xxxx1101 xxxxxxxx xxxxxxxx
15	x x x x 1 1 1 0	8 bits x 1	16	xxxx1110
16	x x x x 1 1 1 1	8 bits x 1	16	xxxx1111

The **mode** notation indicates how many bus address cycles must take place and how many bits are placed on the bus each cycle. For example, "5 bits x 3" means 3 bus cycles and 5 address bits each time.

Building Your Own

PLCBus expansion devices must be designed according to the following rules:

1 The device must have two 26-pin headers that match the PLCBus signals and operate according to those signals.

2 The device must not rely on critical timing, such as a minimum delay between successive register accesses.

3 The device must be capable of being selected and deselected at any time without adverse effect.

4 The device must operate according to the first level addressing rules given here. They do not have to operate according to the second level rules given next, but must not interfere with devices that do.
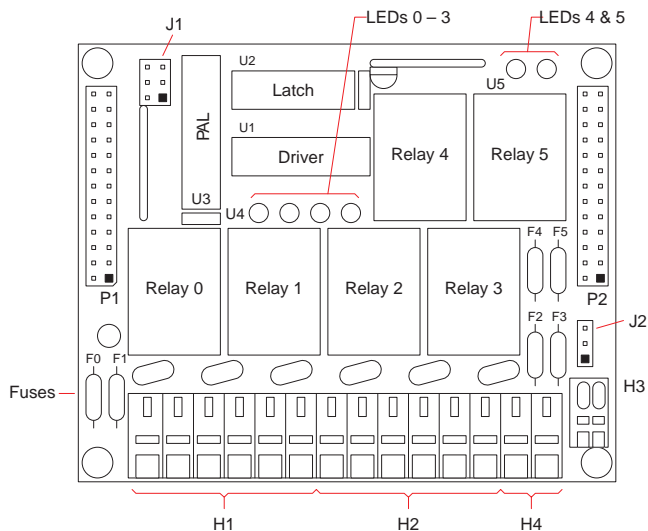
Relay Boards

Z-World's RELAY6 (XP8300) and RELAY8 (XP8400) expansion boards provide a simple way to add relays to your control system. Up to 64 relay boards can be addressed on a single bus.

The RELAY6 board has six high-power relays installed as standard equipment. The board has six LEDs that correspond to the six relays. An LED turns on while the corresponding relay's coil is activated.

The RELAY8 board has eight DIP relays installed as standard. Other types are acceptable. A single LED on the board flashes any time the board has been addressed.
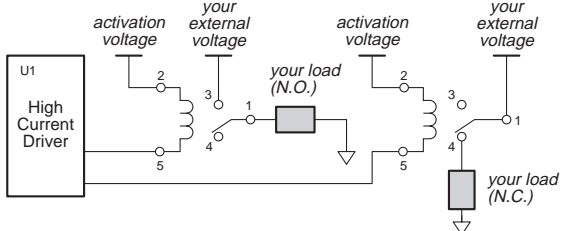
Relay 6

The RELAY6 board has six 10A SPDT relays. Headers H1, H2, and H4 connect the external world to the relays. Jumper J1 (along with PAL encoding) determines the board's bus address. Jumper J2 affects the relays' actuation voltage.

The relays installed by Z-World have the following specifications:

Configuration: SPDT
Coil Actuation Voltage: 24 VDC
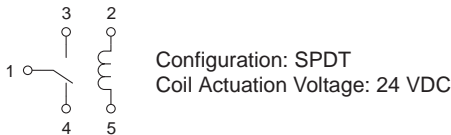
Pin 5 connects to the high-current (sinking) driver on the relay board. Pin 2 is for the actuation voltage. Turning on the sink allows current to flow through the coil, switching on the relay. Pin 3 is the normally open output. Pin 4 is the normally closed output. Pin 1 is common to N.O. and N.C. outputs.

Each relay is protected by a 10A fuse. To reduce or eliminate transients, a metal oxide varistor (MOV) is connected between pins 1 and 3 on each relay.

Headers H1, H2 and H4 connect your system's devices to the relays. Pin 1 (common) and pin 3 (N.O.) connections for all six relays are provided on H1 and H2. Header H4 provides the pin 4 (N.C.) connections for relays 4 and 5.
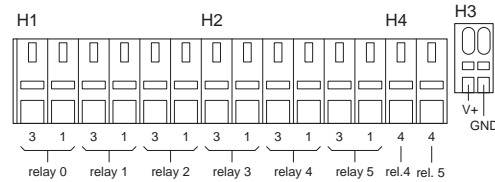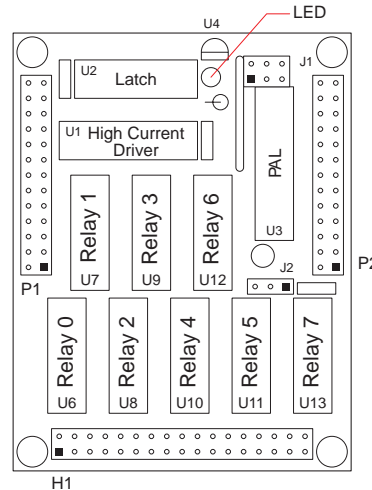

Jumper J2 affects the actuation voltage for the board's relays. When J2:1-2 is connected, the actuation voltage is supplied by the +V line on the PLCBus. When J2:2-3 is connected, the actuation voltage is supplied by the VCC line on the PLCBus.
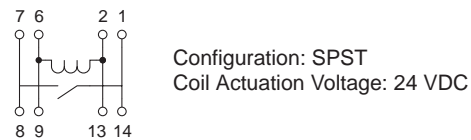
To supply actuation voltage at header H3, leave J2 unconnected and connect your power supply at V+ and GND.

Relay 8

The RELAY8 board has eight 500 mA DIP relays. Header H1 (34 pins) connects the external world to the relays. Jumper J1 (along with PAL encoding) determines the board's bus address. Jumper J2 affects the relays' actuation voltage.

The relay installed by Z-World as standard equipment has the following specifications:

Configuration: SPST
Coil Actuation Voltage: 24 VDC

the +V line on the PLCBus. When J2:2-3 are connected, the actuation voltage is supplied by the VCC line on the PLCBus.

To supply actuation voltage at header H1, leave J2 unconnected and connect your power supply at V+ and GND.

How to use Relay Boards

Whether you are using a RELAY6 board or a RELAY8 board, the method for controlling it is the same:

1 Initially, send a reset command to all boards on the PLCBus. Wait 350 ms.

2 Get the board's attention by placing its address on the PLCBus.

3 Operate the various relays on the board.

Addressing a Relay Board

Up to 64 relay boards (RELAY6 and RELAY8 boards in any combination) can be addressed individually on a single PLCBus. The address of a particular relay board is determined (1) by the encoding of the PAL chip installed on the board and (2) by jumper J1. Eight different PALs are available and J1 can be set eight different ways, giving 64 unique addresses:

000z 000y pppx

z = 1 when J1 pins 5-6 are not connected
y = 1 when J1 pins 3-4 are not connected
x = 1 when J1 pins 1-2 are not connected.

The bits *ppp* are determined by the PAL number. Software gives the relay boards *logical addresses*, 0–63, using this formula:

logical address = $ppp \times 8 + zyx$

where *ppp* and *z, y,* and *x* are defined above.

Controlling a relay

Once you have placed a relay board's address on the bus, you may switch its relays at will. Using BUSWR, place four bits of data on the bus:

Relay	D3	D2	D1	Relay	D3	D2	D1	D0
0	0	0	0	4	1	0	0	0 = relay off
1	0	0	1	5	1	0	1	1 = relay on
2	0	1	0	6	1	1	0	
3	0	1	1	7	1	1	1	

Notes

Each relay on the RELAY6 board has an LED that illuminates when the corresponding relay is activated. This does not provide verification that the contacts within the relay actually switch, however.

Specifications

RELAY6 (XP8300)

|	
Board Size	$2.835 \times 3.525 \times 0.78$
Operating Temp	–40°C to +70°C
Humidity	5% to 95% non-condensing
Power	24VDC, 100 mA
Relays	6 SPDT (contacts rated 120VAC at 10A).

RELAY8 (XP8400)

Board Size	$2.835 \times 2.22 \times 0.58$
Operating Temp	–40°C to +70°C
Humidity	5% to 95% non-condensing
Power	24VDC, 80 mA
Relays	8 SPST (contacts rated 150VDC at 500 mA).

ADC Boards

Z-World's A/D12 and ADC4 expansion boards add analog-to-digital (ADC) channels to your control system. You can address up to 64 A/D12 boards and up to 16 ADC4 boards on a single PLCBus.

The A/D12

The A/D12 board has eight analog input channels. These can be read as eight differential signals with selectable gain, or as 16 single-ended signals with unity gain. Gains of 2, 6, 22, 42, 102, and 202X, as well as unity gain, can be selected.
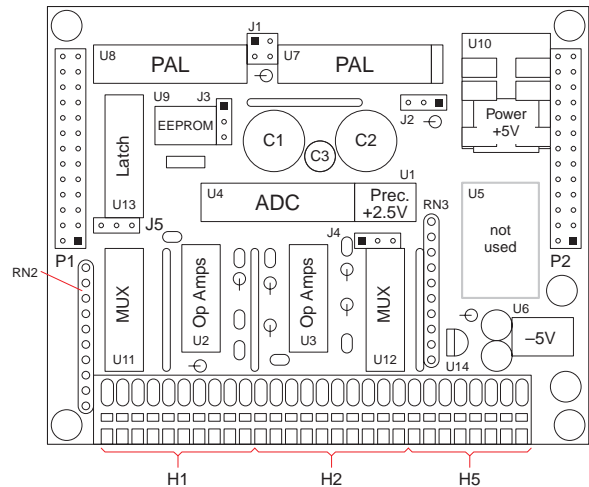

Each A/D12 board is factory-calibrated. Compensation coefficients for all ADC channels are stored in the board's EEPROM. The EEPROM can be read or written by your application program. Normally, you would not do this. However, you might wish to recalibrate your A/D12 board at some point.

The A/D12 board's main power supply provides +5V up to 1 amp. U6 and U14 provide V–, a regulated –5V up to 50 mA. An LT1019 provides a precision 2.5V reference up to 10 mA.

External Connection

Analog signals enter the A/D12 board via terminals on connectors H1 and H2. A third connector, H5, provides excitation voltages for strain gauges and other analog input sensors. Signals at the board's input terminals (ANx+ and ANx–, $0 \leq x \leq 7$) are routed to the board's ADC chip, U4, by two multiplexers and several differential amplifiers.
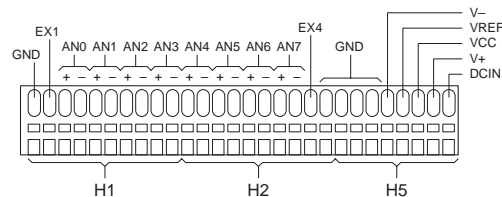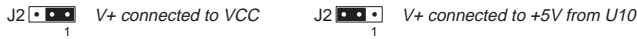
Jumpers

The A/D12 board uses 4 jumpers, J1 through J4. Settings for J1, coupled with the encoding of the PAL chip U7, determine the board's PLCBus address. These settings are explained later.

J1 — Connect for address bit "x" = 0
— Connect for address bit "y" = 0
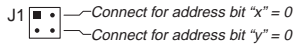
Jumper J2 directs power for the board's analog circuitry.

J2 V+ connected to VCC   J2 V+ connected to +5V from U10

Jumper J3 is a write-protect switch for the EEPROM (U9).

J3 Write-protect   J3 Write-enable

Jumper J4 routes a reference voltage to the A/D conversion chip U4. The factory setting connects pins 2-3, routing U1's precision 2.5V reference output to the A/D chip. Connecting pins 1-2 routes the "ratiometric" voltage (RM) to the A/D chip. (When $R7 = 0$ and R3 is not installed, $RM \approx V+$.)

J4 Route RM to A/D chip   J4 Route precision +2.5V to A/D chip

The Analog Circuitry

The A/D12 board's eight inputs (ANx+ and ANx–) are routed to the board's ADC chip by two analog multiplexers and several differential amplifiers. Gains of 2, 6, 22, 42, 102, and 202X, as well as unity gain, can be selected by software.
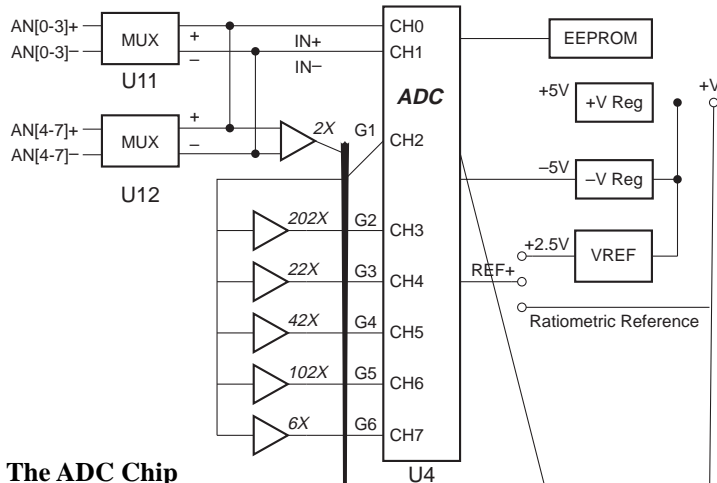
The ADC Chip

The ADC chip, a 12-bit LTC1294, can convert a signal at one of its input pins in either of two modes: unipolar or bipolar. The chip's allowable input range and output values are as follows:

Mode	Input Range	Output Range
Bipolar	–2.5V to +2.5V	–2048 to +2047
Unipolar	0 to +2.5V	0 to 4095

You can reduce a voltage input to the required range with a resistor network. Otherwise, when an input voltage falls outside the supported range, the chip responds with its maximum or minimum value.

How to Use an A/D12 Board

Generally, this is what you do:

1 Initially, send a reset command to the PLCBus.

2 Place the address of the board on the PLCBus.

3 Read one of the A/D12 board's input channels. Allow for MUX settling time.

4 Calculate real-world values, such as temperature or displacement, from the data obtained.

5 Use the data (to control relays, switches, or other devices).

Once an A/D channel has been set up, you can read it repeatedly, as fast as 165 µsec per read (on a 9 MHz controller).

Addressing the board

The address of a particular A/D12 board is determined (1) by the encoding of PAL chip U7 installed on the board and (2) by jumper J1. Sixteen different PALs are available and J1 can be set four different ways, giving 64 unique addresses:

000p 10px ppRy

R = 0 for register S3A, 1 for register S3B
y = 1 when J1 pins 3-4 are not connected
x = 1 when J1 pins 1-2 are not connected

The bits *pppp* are determined by the PAL number.

For a given board, the R bit selects one of two hardware registers—S3A or S3B—coded on the PAL chip. S3A is a "MUX control register" that selects one of the board's eight input channels. S3B is the "serial communication control register."

The A/D12 expansion boards have *logical* addresses, 0–63, according to this formula:

logical address = $pppp \times 4 + xy$

where *pppp*, and *y* and *x* are defined above.

A/D Conversion Modes

When reading a differential input signal, connect the sensor to both ANx+ and ANx–. When reading a single-ended signal, connect the voltage source to ANx+ and connect ANx– to GND. When reading a unity-gain single-ended signal, no ground is necessary. Simply connect the voltage source to the desired terminal (ANx+ or ANx–).

(When reading the A/D chip with Z-World software, specify the desired gain and polarity by selecting a particular "A/D mode." There are 18 different A/D modes.)

Input Stability

Grounded input signals were used to calculate the standard deviations of "A/D channels." Tests of 1000 samples per channel were performed on typical boards in both unipolar and bipolar modes. Under these conditions, the standard deviation for all channels was under 1 part in 2047, and very near 0.1 part in 2047 for small gain values.

MUX Settling Time

When switching MUXs, you must allow the circuitry to settle before attempting to read the A/D output. Capacitors C10–C14 (330 pF) attached to the feedback on gain amplifiers are the greatest contributors of delay.

Reducing the size of the feedback capacitor reduces the settling time, at the expense of noise filtering.

EEPROM Coefficients

Compensation coefficients, determined by precise measure-
ment, are stored in the on-board EEPROM for each of the 18
software A/D modes.

**Measurement of Ambient Temperature**

The TEMP pin on U1 (LT1019) puts out a voltage that is directly
proportional to absolute temperature, with a slope of 2.1 mV
per degree. Room temperature (295°K) generates ~620 mV.

Excitation Voltage at Each Input

To provide an excitation voltage at each input channel on head-
ers H1 and H2, install RN2 and RN3 on the board and connect
EX1 (on H1) and EX4 (on H2) to V+ on header H5.

The ADC4

Z-World's ADC4 expansion board adds eleven 12-bit ADC chan-
nels to your system. Four channels have signal conditioning
that can match your input voltage range. The ADC4 board nor-
mally operates at 24V, but will operate at 12V.
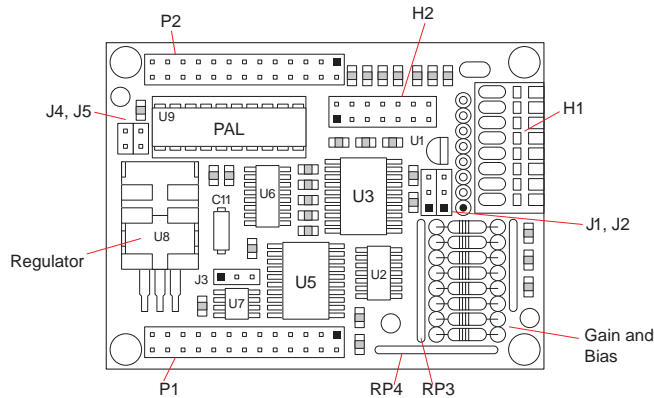
The four channels (CH0–CH3) that have signal-conditioning
circuitry, as shown below. You can match the voltage range of
the device you are measuring to the fixed voltage range (2.5V)
of the ADC chip by changing socketed resistors (labelled *GAIN*
and *BIAS* here).
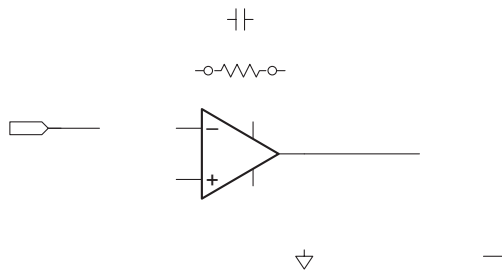
Setting Up Your Conditioned Inputs

As they comes from the factory, the conditioned inputs have a 0–10V input range. The socketed resistors are 2370 Ω (gain) and 39.2 kΩ (bias) respectively.

You can have any input range you want, simply by changing the gain and bias resistors. The following tables present some useful input ranges. The table values require 1% resistors and have been adjusted from the theoretical values to account for tolerance.

Input Range (V)	Gain	R_{GAIN} (Ω)	R_{BIAS} (Ω)	
–10.0 to +10.0	0.125	1180	8060	
–5.0 to +5.0	0.250	2370	6650	
–2.5 to +2.5	0.500	4750	4990	
–2.0 to +2.0	0.625	5900	4530	
–1.0 to +1.0	1.250	11.8K	2870	
–0.5 to +0.5	2.500	23.7K	1690	
–0.25 to +0.25	5.000	47.5K	931	
–0.10 to +0.10	12.500	118	392	
0 to +10.0	**0.250**	**2370**	**39.2K**	*Default*
0 to +5.0	0.500	4750	20.0K	
0 to +2.5	1.000	9530	10.0K	
0 to +1.0	2.500	22.6K	4020	

Using the Unconditioned Channels

The unconditioned channels are CH4–CH10.
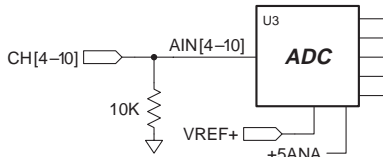
For optimal results, drive the unconditioned inputs with low-impedance voltage sources. Operational amplifiers (such as the LM660) are ideal for the purpose. High-impedence signal sources are susceptible to noise.

Low-Pass Filter

The 0.01 µF capacitors in the op-amp circuitry function as low-pass filters. The filter characteristics depend on the resistors you select. The 3dB corner frequency is given by

$$f_{3dB} = \frac{1}{2\pi \times R_{GAIN} \times 0.01\,\mu F}$$

If the input range is 10V, for example, the gain resistor is 2370Ω and the 3dB corner frequency is 6715.4 Hz.

Drift

The AD680JT voltage reference has a typical drift of 10 ppm per °C and a maximum drift of 30 ppm per °C. These values correspond to 25 (typ) and 75 (max) µV per °C and 1.75 (typ) and 5.25 (max) mV over the range 0–70°C.

The LMC662C op-amp has an offset voltage drift of 1.3 µV per °C, or 910 µV over the range 0–70°C.

Other contributers to overall drift are the 10K resistors R21–R24. These have temperature coefficients of ±100 ppm per °C, or 1W per °C. But, because they are small, surface-mounted resistors, all close to each other, their temperature deviations match closely.

Using the Analog Inputs

Software is available to read and to calibrate the analog inputs. Once calibrated, the calibration values reside in non-volatile memory. All subsequent analog readings will use the calibration values and give the best possible value.

ADC4 Board IDs

You can address up to 16 ADC4 boards on a single bus, since four different PALs are available and the address jumpers J4 and J5 can be set four different ways:

    0000 1100 ppxy

    x = 1 when J5 is open, else 0
    y = 1 when J4 is open, else 0.

The bits *pp* are determined by the PAL number.

Specifications

A/D12

|	
Board Size	2.835 × 3.525
Operating Temp	–40°C to +70°C
Humidity	5% to 95% non-condensing
Power	24VDC, 100 mA
Provides	Eight configurable 12-bit channels. (16 channels if single-ended, unity gain.)

ADC4 (XP8500)

Board Size	2.835 × 2.12 × 0.75
Operating Temp	–40°C to +70°C
Humidity	5% to 95% non-condensing
Power	24VDC, 32 mA
Provides	Eleven 12-bit ADC channels, 4 with signal conditioning.

DAC Boards

The DAC2

Z-World's DAC2 (XP8600) expansion boards add digital-to-analog conversion (DAC) channels to your control system. Up to 64 DAC2 boards can be addressed on a single PLCBus.
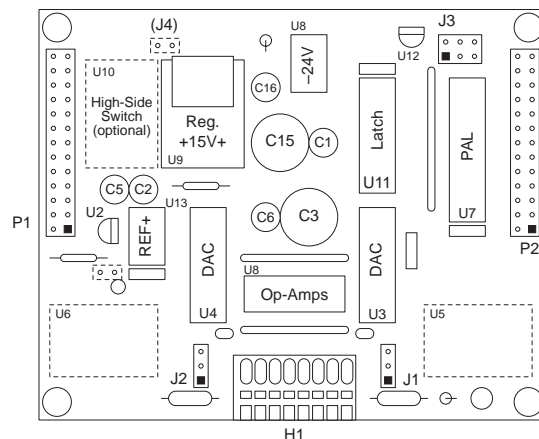

The DAC2 board has two digital-to-analog output channels. Each of these can be operated either as a voltage source or a current source. The default range for voltage output is 0–10V. The default range for current output is 0–22 mA. The D/A chips—AD7543s—have a linearity of ±1 LSB and a gain stability of about 5 ppm per °C.

The DAC2 board's main power supply (U9) provides +15V up to 1 amp. U8 and U2 provide V–, a regulated –5V up to 50 mA. U13, an LT1021 (the factory setting) provides a precision 10V reference (REF–). Optionally, you may install an LT1019 for U13. This provides a precision 2.5V reference for REF–. A third option is to leave U13 vacant and install a zener diode at Z1. The actual reference voltage depends on the sizes of Z1 and R4.

External Connection

Analog signals (voltage or current output) leave the DAC2 board via terminals 1 and 3 on header H1. Other terminals provide access to board voltages.
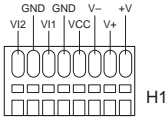
When used with most Z-World controllers, the +V (normally +24V) from the PLCBus is the power source, accessible on H1. When using the DAC2 board with some controllers, +24V is not available from the PLCBus. You must supply +24V on H1.

Jumpers

The DAC2 board uses 3 jumpers, J1 through J3. Settings for J3, coupled with the encoding of the PAL chip U7, determine the board's PLCBus address. These settings are explained later.

Jumpers J1 and J2 determine the mode of output channels 1 and 2 (VI1 and VI2, on H1). Connecting pins 2-3 selects voltage output. Connecting pins 1-2 selects current output:

### LED

The DAC2 board has an LED (D1) which illuminates whenever the board's address is placed on the PLCBus.

Reset

The DAC2 board has a reset device, U12, that monitors VCC. Whenever VCC is interrupted, U12 pulls /RST low. Thus, you can force the board to reset with software or a push-button.

The Circuitry

The DAC2 board's digital-to-analog circuitry comprises two l2-bit AD7543s, U3 and U4, and an LM324N quad op-amp chip, U1. The outputs of the DACs are amplified, providing either current output or voltage output. The outputs appear at jumpers J1 and J2 as well as at header H1. Digital input values come, via the PLCBus, from the program running on the controller.
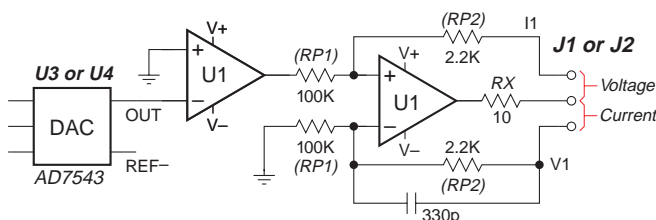
Capacitors C7 and C8 are normally not installed. For applications that operate at more than ~100 Hz, install C7 and C8.

The AD7543 Chip

Each of the two AD7543s receives serial data in register A. When register A is full, its contents are transferred to register B. The data are then converted and analog level is output.
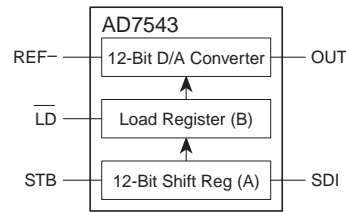
Each AD7543 has a linearity of ±1 LSB and a gain stability of approximately 5 ppm per °C.

The output of each DAC is given by the following formula:

$$OUT = -(input/4096) \times REF-$$

The DAC output voltage ranges from 0 to REF–. When U13 is an LT1021 (the factory default) REF– is 10V.

Voltage Output

When voltage output is selected, the output is given by the following formula:

$$V = OUT \times (1 + RP2/RP1)$$

where OUT is the output of the DAC chip. Output values can be changed by changing resistor packs RP1 and RP2. The maximum output voltage is limited by the op-amp to 14V.

Current Output

When current output is selected, the output is given by the following formula:

$$I = (OUT/RX) \times (RP2/RP1)$$

Output values can be changed by changing resistor packs RP1 and RP2. The maximum output current is limited by the op-amp to 22 mA.

How to Use a DAC2 Board

Generally, this is what you do:

1 Initially, send a reset command to the PLCBus.

2 Place the address of the DAC2 board on the PLCBus.

3 Send data to one of the DAC2 board's two DACs (register A). When register A is filled, transfer the data to DAC2 register B where it is converted and output. There is software that does this.

4 Use the analog output (to control motors, attenuators or other analog devices).

Addressing the board

Up to 64 DAC2 boards may be addressed individually over a single PLCBus. The address of a particular DAC2 board is determined (1) by the encoding of PAL chip U7 installed on the board and (2) by jumper J3.

Eight different PALs are available and J3 can be set eight differ-ent ways, giving 64 unique addresses:

000z 001y pppx

z = 1 when J3 pins 5-6 are not connected
y = 1 when J3 pins 3-4 are not connected
x = 1 when J3 pins 1-2 are not connected

The bits *ppp* are determined by the PAL number. Software gives DAC2 expansion boards *logical* addresses, 0–63, according to the formula:

logical address = $ppp \times 8 + zyx$

where *ppp* and *z*, *y* and *x* are defined above.

Current Consumption

With no output, the DAC2 board draws 30 mA. With both output channels operating at maximum current (22 mA) the DAC2 board draws a total of 75 mA.

DAC2 Specifications

|	
Board Size	$2.835 \times 3.525 \times 0.75$
Operating Temp	–40°C to +70°C
Humidity	5% to 95% non-condensing
Power	24VDC, 30 mA
Provides	Two 12-bit DAC channels, rated 0–10V voltage output or 0–22 mA current ouput.

The DAC8

Z-World's DAC8 (XP8900) expansion boards add digital-to-ana-log conversion (DAC) channels to your control system. Up to 8 DAC8 boards can be addressed on a single PLCBus.
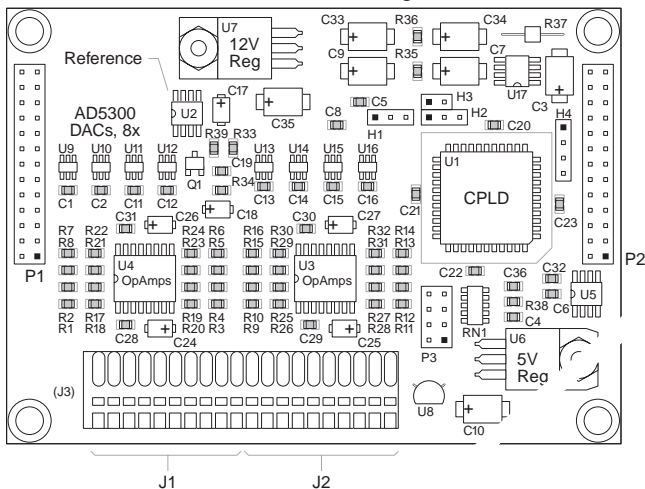

The XP8900 has eight channels. The XP8910 has four channels. Each channel be operated as a bipolar voltage source. The fac-tory default range for voltage output is –10V to +10V. Each channel can source or sink 2 mA on internal power or 7 mA with external power. The D/A chips—AD5320s—are accurate to ±16 LSB and have a gain stability of about 5 ppm per °C.

In sufficient quantity, Z-World will build XP8900s with from 1 to 8 channels, with 8- or 10-bit DACs, or with customer-defined ranges.

The board's main power supply (U2, U6, U7, U17) provides +5V (VCC), +5V reference for the DACs and +12V and –12V "rails" for the op-amps. Q1 switches a +2V reference voltage to the op-amps for power conservation. Jumpers H1, H2 and H3 allow you to connect external ±12V rails to the op-amps if you wish. Ex-ternal power has a higher current rating.
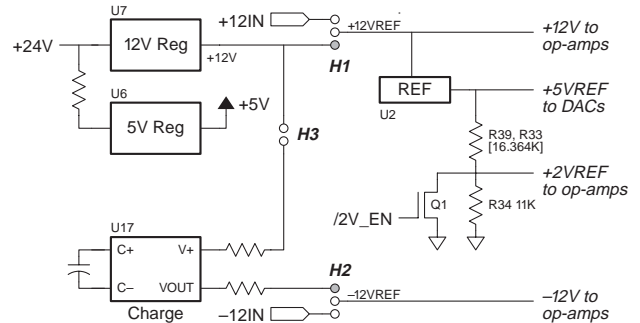
Data are clocked into the DACs (low-power AD5300s). Output of a DAC feeds into an op-amp which adjust the output to the desired range.
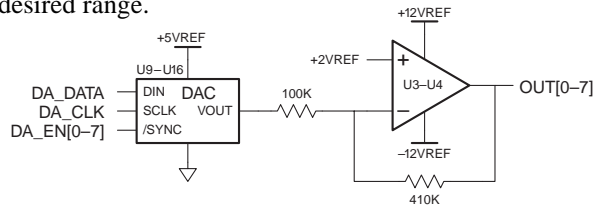
The default range is –10V to +10V. In sufficient quantity, you can order your DAC boards with different output ranges.
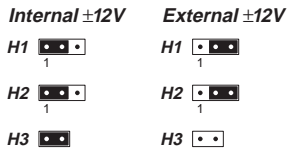
External Connection

Analog signals leave the XP8900 on Wago headers J1 and J2. Two terminals allow you to use external ±12V to power the channel op-amps. Each channel has its own ground terminal.

Jumpers

The DAC8 board uses 3 jumpers, H1 through H3 to select the ±12V source:

Internal ±12V   **External ±12V**

H1   H1

H2   H2

H3   H3

EEPROM

The DAC8 board's EEPROM (U5) stores calibration constants and is controlled by the CPLD (U1).

CPLD

The DAC8 board's CPLD (U1) encapsulates the board's logic. It monitors PLCBus addresses to determine if the board is being addressed. When the board is being addressed, the CPLD examines the low 2 bits of the address. These 2 bits identify the current DAC8 operation:

| Bits	Mode	Description
00	DAC	Write to a selected DAC. Bit 0 of BUSWR is for data; bit 1 clocks the data.
01	EE	Read or write the EEPROM. BUSWR: Bit 0 = data; bit 1 = clock. BUSRD0: Bit 0 = data.
10	Select	BUSWR: when data = 0111, turn on 2V ref. BUSWR: when data = 0110, turn off 2V ref. BUSWR: when data = 1*xxx*, turns on channel *xxx* (0–7). BUSRD0: reads 1010 when board is present.

The CPLD can enable or disable DAC output (by turning on and off the 2V reference).

The AD5320 Chip

The AD5320 is a single 12-bit DAC operating from a single 2.7–5.5V supply. It has an on-chip output amplifier that allows true rail-to-rail output swing. Its reference is derived from the power input. Its output is guaranteed monotonic.

The AD5320 sinks/sources 140 µA at 5V during normal operations and 200 nA in power-down mode. There are three power-down modes; the differences between them are not relevant.

Each of the eight AD5300s receives serial data in a 16-bit shift register. Two bits represent "power-down mode" (normal mode is 0). The low 12 bits represent the output value:
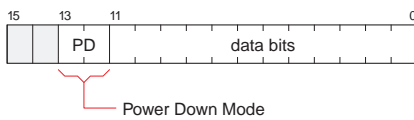
Following the 16-bit sequence, the CPLD strobes the DAC chip. The output of each DAC is given by the following formula:

$$V_{OUT} = V_{REF} \times (input / 4096)$$

where V_{REF} is +5V from U2.

Bipolar and Unipolar Operation

The AD5320 was designed for unipolar operation, but with an op-amp and the right resistors, bipolar output can be achieved. The default output for the XP8900 is bipolar. The formula for output on the XP8900 is

$$V_{OUT} = V_{REF} \times \frac{input}{4096} \times \frac{R_2}{R_1} - 2 \times \frac{R_1 + R_2}{R_1}$$

The XP8900 has, by default, $R1 = 100K$ (two 200K resistors in parallel) and $R2 = 410K$ (two 205K resistors in series). Thus,

$$V_{OUT} = 5 \times \frac{input}{4096} \times \frac{410}{100} - 2 \times \frac{100 + 410}{100}$$

$$= 20.5 \times \frac{input}{4096} - 10.2$$

giving a full range from –10.2V to +10.3V:
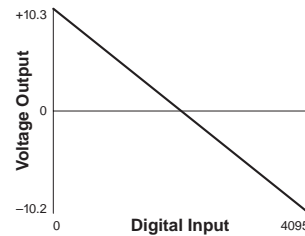
How to Use a DAC8 Board

Generally, this is what you do:

1. Initially, send a reset command to the PLCBus.

2. Place the address of the DAC8 board on the PLCBus. The low two bits of the address select the type of operation as described previously.

3. Carry out a read or write. Some details follow.

4. Use the analog output (to control motors or other analog devices).

Addressing the board

Up to 8 DAC8 boards may be addressed individually over a single PLCBus. The address of a particular DAC8 board is determined by 3 jumpers at P3. The address bits are:

0010 000z yxMM

z = 1 when P3 pins 1-2 are not connected
y = 1 when P3 pins 3-4 are not connected
x = 1 when P3 pins 5-6 are not connected

The bits *MM* determine the DAC8 operation, as described previously. Software gives DAC8 expansion boards *logical* addresses, 0–7, according to the formula:

logical address = *zyx*

Typical Operations

In the examples given below, the shorthand notation

```
BUSxxx value
```

stands for this assembly code

```
ld   a,value
out0 (BUSxxx),a
```

Perform board check

```
BUSADR0   0010
BUSADR1   000z
BUSADR2   yx10  ;select mode
BUSRD0    value ;1010 if board exists
```

Turn analog section on or off

```
BUSADR0   0010
BUSADR1   000z
BUSADR2   yx10  ;select mode
BUSWR     011a  ;a is 1 for on, 0 for off
```

Select a channel

```
BUSADR0   0010
BUSADR1   000z
BUSADR2   yx10  ;select mode
BUSWR     1xxx  ;xxx is channel (0-7)
```

Drive a channel

```
Select the channel, then...

BUSADR0   0010
BUSADR1   000z
BUSADR2   yx00  ;data mode

Repeat
  BUSWR   000d  ;d is data
  BUSWR   001d  ;bit 1 is clock
  BUSWR   000d  ;not change clock same time as data
for each of 16 bits
```

Read or write the EEPROM

```
BUSADR0   0010
BUSADR1   000z
BUSADR2   yx01  ;EE mode

BUSWR     0000  ;Init EE clock and data bits

Make transaction with EE. Serial reads and writes

BUSWR     0000  ;Re-init the EEPROM
```

Current Consumption

The DAC8 board draws approximately 30 mA at 24VDC.

The AD5320s are single-channel 12-bit DACs. They consume very little power: 140 µA at 5V and can power down to 200 nA (at 5V). The contribution of the DAC channels to current consumption is negligible.

The effect of power-down mode is also negligible.

DAC8 Specifications

Board Size	$2.835 \times 3.525 \times \sim0.75$
Operating Temp	$-40°C$ to $+70°C$
Humidity	95% r. h., non-condensing
Power	24VDC, 30 mA
Provides	Eight (or four) 12-bit DAC channels, output rated $-10V$ to $+10V$.

Each AD5320 has a linearity of ±16 LSB and a gain stability of approximately 5 ppm per °C.

The RS232 Board

Z-World's RS232 (XP8700) expansion boards provide a simple way to add an RS232 channel to your control system. Each board has a single Signetics SCC2691 UART. Up to 4 RS232 boards can be addressed on a single PLCBus.
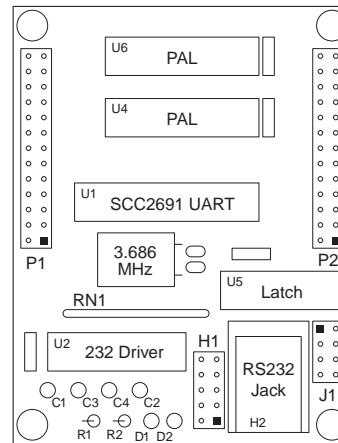
To operate the RS232 board's UART, you read and write to two registers on the RS232 board: the control register (CTRL) and data register (DATA). In addition, the RS232 board can raise a processor interrupt INT1.

The SCC2691 UART

The SCC2691 is a full-duplex asynchronous receiver/transmitter. It supports 18 baud rates from 50 to 38,400 baud. Data may be framed with from 5 to 8 data bits, four parity modes, and 1, 1.5, or 2 stop bits. The UART provides error detection (framing errors, parity errors, and overrun errors), break detection and generation, and echo. There are two diagnostic modes. The chip also has a multifunction 16-bit counter/timer.
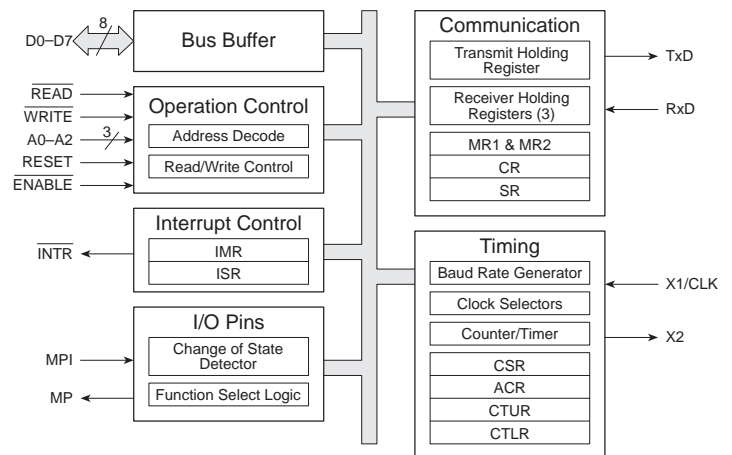
The chip will generate interrupts under seven maskable conditions. It has a low-power mode and a "wake-up" mode. Receiver data are buffered (4-byte FIFO).

Control of the UART is accomplished by reading or writing its internal registers. You may set up a counter or timer, initiate RS232 communication, or control interrupts. Options include setting baud rates, parity and other modes.

There are 14 internal registers, 7 of which you can read and 9 of which you can write:

A2	A1	A0	Read	Write
0	0	0	MR1, MR2	MR1, MR2
0	0	1	SR	CSR
0	1	0	*Reserved*	CR
0	1	1	RHR	THR
1	0	0	*Reserved*	ACR
1	0	1	ISR	IMR
1	1	0	CTU	CTUR
1	1	1	CTL	CTLR

If the UART is being read, one set of registers is addressed. If it is being written, the other set is addressed.

Refer to the Signetics SCC2691 product description.

How to Use the RS232 Board

Generally, this is what you do:

1 Initially, send a reset command to the PLCBus.

2 Place the address of one of the RS232 board's registers on the bus. Write a reset command to an RS232 board's CTRL register.

3 As needed, write to the internal registers of the board's UART to control the UART. Read the UART's internal registers to find out how things are going.

4 Read the RHR (receive holding register) or write to the THR (transmit holding register) to communicate.

Connections

There are two RS232 connectors on the board, a 10-pin header, H1, and a 6-wire "phone jack," H2. You can use either one.

Header H1   Jack H2
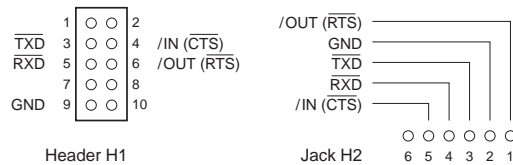
Addressing the board

There are two registers on an RS232 board, the control register and the data register. Each is addressable on the PLCBus. The address of an RS232 board register is determined by jumper J1.

J1 can be set four different ways, giving up to 4 RS232 boards per bus. Each register's 15-bit address has this format:

    00100 00000 xy00R

R = 0 for CTRL register, 1 for DATA register
y = 1 when J1 pins 3-4 are not connected
x = 1 when J1 pins 1-2 are not connected.

Software gives RS232 expansion boards *logical* addresses, 0–3, according to the following formula:

    logical address = xy

where x and y are described above. Observe that, for any RS232 board, the DATA address = CTRL address + 1.

Reading and Writing to the UART

The PLCBus cycles have specific meaning when addressing an RS232 board.

BUSWR	Write data to either CTRL or DATA register.
BUSRD0	Read RS232 board status. Bit 0 (when 0) indicates the presence of an RS232 board. Bit 1 (when set) indicates that the UART needs servicing. This read is valid only when the board's CTRL register has been addressed.
BUSRD1	Read the UART internal register selected by the board's CTRL register. This read is valid only when the board's DATA register has been addressed.
BUSRESET	Resets all expansion cards on the PLCBus. However, an RS232 board *does not respond* to this. The UART is reset with the RESET bit of the CTRL register.

Controlling the UART

To control the UART on the RS232 board, you send data to, or read data from, one of its internal registers. This uses the board's control and data registers. This is the control register:

—	—	$\overline{CE}$	A0	RESET	A1	LT1180 ON	A2
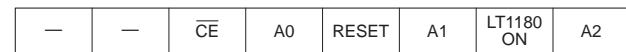
/CE	Enables the UART chip when low. The UART must be enabled to read from it or write to it.
A0–A2	Select one of the UART's internal registers. The register selection depends also on whether you are reading or writing and whether MR1 or MR2 has been selected.
RESET	Resets the UART.
LT1180 ON	When set, enables the LT1180 RS232 driver. When clear, reduces power consumption.

The RS232 board can communicate with any RS232 device. When a modem is used with the RS232 board, TX of the RS232 board must be connected to RX of the modem and vice versa. Connecting a null modem between the RS232 board and the modem takes care of this.

Interrupts from the RS232 Board

The RS232 expansion board has the capability of interrupting your controller through the INT1 line whenever

1 a character has been received (RXRDY)
2 the transmit buffer is empty (TXEMT)

When such an interrupt occurs, your program may check for errors (parity, framing, and overrun errors).

The /AT line of the PLCBus is connected to INT1 of the Z180. There may be more than one interrupting device on the PLCBus. An interrupt service function must check all devices that could possibly have caused the interrupt, and service the devices that need service.

You can also test whether an RS232 expansion card is interrupting by executing a BUSRD0 cycle. If you get a zero result, the board generated no interrupt.

RS232 Board Specifications

Board Size	$2.835 \times 3.525 \times 0.75$
Operating Temp	–40°C to +70°C
Humidity	95% r. h., non-condensing
Power	24VDC, 80 mA
Provides	One full-duplex RS232 port. Up to 57,600 bps.

Universal Input/Output Board

Z-World's Universal Input/Output board (XP8800) adds 16 *universal* inputs and six high-current outputs to your control system. The universal inputs can be used as

- digital inputs with single fixed threshold
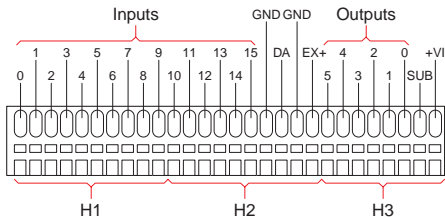- digital inputs with two adjustable thresholds
- analog inputs.

For the latter 2 cases, an external voltage source is required.
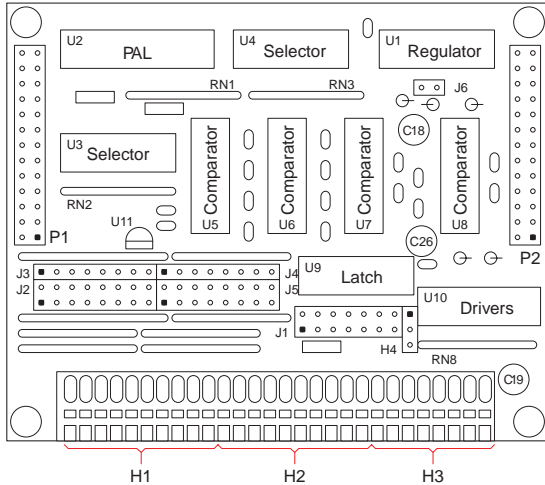
Up to 32 XP8800 (UIO for short) boards can be addressed on a single PLCBus.

External Connection

The universal inputs (IN0–IN15) appear on headers H1 and H2. High-current outputs (/L0–/L5) appear on header H3.

Pins	Description
IN0–IN15	Universal inputs
GND	Board ground
DA	External voltage source (presumed to be a DAC).
EX+	External excitation voltage.
/L0–/L5	High voltage driver outputs.
+VI	External supply voltage for devices driven by /L0 through /L5.
SUB	External supply ground.

Jumpers

The UIO board uses 7 jumpers, J1 through J6 and H4. Pins 1 and 2 of jumper J1, coupled with the encoding of the PAL chip U2, determine the board's PLCBus address. This is explained later.

The signals on J1 are shown here:


Pins	Description
1-2	Least significant bit of board address (1 if not connected).
3-5	Comparator voltage CV+ connected to VCC.
5-7	Comparator voltage CV+ connected to V+ (default).
4-6	Reference voltage connected to external excitation voltage (EX+).
6-8	Reference voltage connected to V+ (default).
9-11	Input voltage to regulator (VH) is +24V from PLCBus (default).
11-13	Input voltage to regulator (VH) is VIN, from external supply.
10-12	Common protective diode K connected to +24V from PLCBus.
12-14	Common protective diode K connected to VIN from external supply (default).

When jumper J6 is connected (it has only two pins) V+ is 7 volts. Otherwise, it is 14 volts.

Jumper H4 selects whether the inputs are digital or "universal."
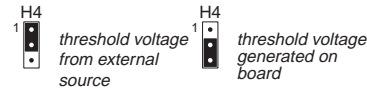
Jumpers J2, J3, J4, and J5 comprise one large header for connecting the universal inputs. There are 16 columns on this header, one for each of the 16 input channels. There are three pins in each column. Connecting the upper two pins pulls a channel's input to ground. Connecting the bottom two pins in a column pulls that channel's input up to the excitation voltage:
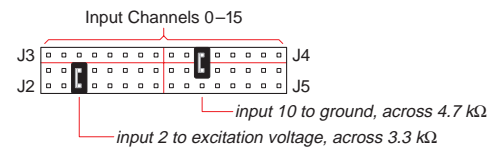
The "Universal" Inputs

The UIO board's 16 inputs (IN0–IN15) are fed to the positive side of 16 comparators. The negative side of the comparators are driven either by an external analog voltage source (DA) or a fixed threshold VL.
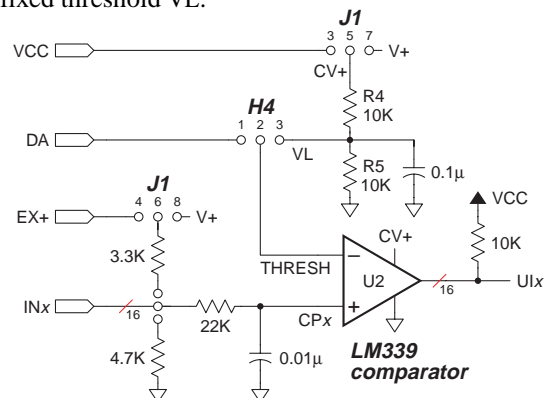
Each input channel can be pulled high to an excitation voltage (which can be external or V+) or pulled to ground, depending on the setting of jumpers J2, J3, J4 and J5.

Universal Inputs As Digital Inputs

When the negative side is connected to VL, the inputs function as digital inputs: the channel read "1" when the input voltage is more positive than its threshold voltage and "0" otherwise. The threshold voltage is given by this expression:

$$V_{THRESHOLD} = CV+ \times \frac{R5}{R4 + R5}$$

### Universal Inputs as Digital Inputs with Two Thresholds

The input channels can be used as digital channels with two (or more) thresholds specified in software when the negative side of the comparator is connected to an external analog voltage source. Presumably, the external source is a DAC operated by the system's controller. (Z-World's PK2100 has such a DAC output.) When an input voltage is higher than its upper threshold, the channel becomes "1" and when it goes below its lower threshold, the channel becomes "0." The digital result does not change (in software) when the input is between thresholds. This feature offers stability for some kinds of inputs.

Universal Inputs as Analog Inputs

The input channels can be used as analog channels when the negative side of the comparator is connected to an external DAC. Because the comparator threshold can be varied, it is possible to take an analog reading by successive approximation. The accuracy of such a reading depends, in part, on the accuracy of the DAC.

The High-Current Output(s)

Six high-current outputs drive external loads (/LO–/L5) such as relays or small actuators.
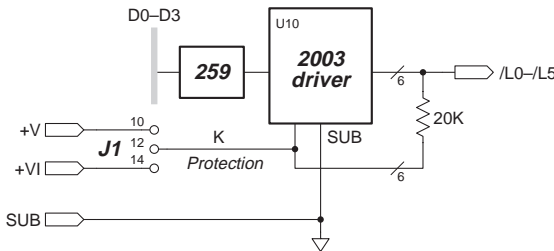
The voltage supplied to the outputs can be +V from the PLCBus or an external voltage (+VI) from the header H3. If you supply an external voltage, connect SUB (also on H3) to external ground. Diodes internal to the 2003 protect the driving transistors against spikes.

The driver chips dissipate up to 1.25W at 60°C. With six channels on at the same time, the maximum current is ~160 mA per channel. The maximum current per channel is 500 mA.

How to use a Universal Input/Output Board

The general method for using a UIO board is this:

1 Initially, send a reset command to all boards on the PLCBus.

2 Get the board's attention by placing its address on the PLCBus.

3 Read the inputs on the board, or perform output.

Addressing the Board

Each UIO board can have one of 16 PALs. Jumper J1 (pins 1-2) be set two ways. Thus, there can be 32 UIO boards on a single PLCBus. Each board's address has this format:

    0000 010p pppx

    pppp is determined by the PAL
    x = 1 when J1 pins 1-2 are not connected.

UIO board addresses, therefore, range from 0x040 to 0x05F. Software give the UIO *logical* addresses. Each UIO channel has an address, according to the formula:

    address = board << 4 + channel.

Operating the Board

The UIO board has 16 universal inputs and six high-current outputs. To access an input channel or an output channel, write to the board's latch using BUSWR:

D3	D2	D1	D0	Meaning	
0	0	0	x	Set or clear /L0	for high-current outputs 0–5
0	0	1	x	Set or clear /L1	
0	1	0	x	Set or clear /L2	
0	1	1	x	Set or clear /L3	
1	0	0	x	Set or clear /L4	
1	0	1	x	Set or clear /L5	
1	1	0	x	*Unused*	
1	1	1	x	Set up a read. When D0=0, select even input channels. When D0=1, select odd input channels	

Setting an output driver is straightforward.

Reading one of the input channels (in digital mode) is slightly more complicated. There are two different read cycles. BUSRD1 corresponds to input channels 0–7. BUSRD2 corresponds to channels 8–15. You must also set up for a read: writing 0xE to the latch selects even input channels. Writing 0xF selects odd input channels. Thus, the BUSRD1 and BUSRD2 cycles read 4 channels at a time, one bit per channel, in D3–D0.

The various bus cycles have specific meaning when using a UIO board:

|	
BUSWR	Write data.
BUSRD0	Determine the presence of a UIO board. Bit 0, when 0, indicates the presence of a board.
BUSRD1	Read input channels [0, 2, 4, 6] or [1, 3, 5, 7].
BUSRD2	Read input channels [8, 10, 12, 14] or [9, 11, 13, 15].
BUSRESET	Resets all expansion cards on the PLCBus.

Higher level functions available in Dynamic C libraries take care of the details of much of this.

Specifications

Board Size	2.835 × 3.525 × 0.75
Operating Temp	–40°C to +70°C
Humidity	5% to 95% non-condensing
Power	24VDC, 45 mA
Provides	16 "universal" channels. 6 high-current output channels, sinking continuously 150 mA at 48V at 50°C (all on) or 500 mA continuously at 48V at 25°C (one channel at a time).

The Stepper Motor Controller

Z-World's stepper motor controller (XP8800) is a special purpose expansion board. This document will use the abbreviation SMC to refer to the stepper motor controller.
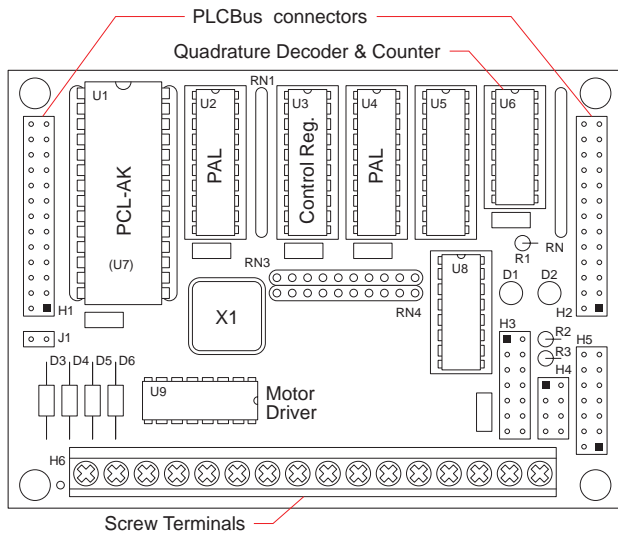
The SMC controls a single axis of motion. You can address up to 16 SMCs on a single PLCBus. The virtue of the SMC is that you can offload motor control operations, leaving your master controller free to perform other tasks.

The motor driver (UCN5804) is capable of driving 1A per phase and motor voltages up to 35V. The driver automatically generates the sequencing for 1-phase, 2-phase, and half-step operations. The SMC includes a 16-bit quadrature decoder/counter (HCTL-2016) which can count at speeds up to 3 MHz.

### System Description

The SMC board has three major components

1 PCL-AK pulse generator
2 UCN5804 motor driver
3 HCTL-2016 quadrature decoder / counter

Many of the SMC features are found in the programmable PCL-AK pulse generator—the "brain" of the SMC.

- Continuous (i.e., manual), preset (i.e., counted), or origin-seeking modes of operation.
- Switching between high- and low-speed operation, with or without acceleration and deceleration.
- "Bidirectional" pulse output modes.
- Sensing of origin, end-limit, and slow-down signals.
- Interrupt generation.
- 13-bit (8191) step rate resolution. 18-bit (256K) counter.
- User-definable output speed range, up to 3 MHz.
- Single-phase, dual-phase, and half-step modes.
- 16-bit quadrature decoder / counter.
- Watchdog safety feature.

The SMC board has a control register (U3) and control logic (U2, U4). You can choose to use or disregard some of the SMC components. For example, you can replace the motor driver with one of your own. The SMC can be used solely as a quadra-ture counter by ignoring the PCL-AK and the motor driver. It can even be used as a timer by ignoring or disabling its outputs.
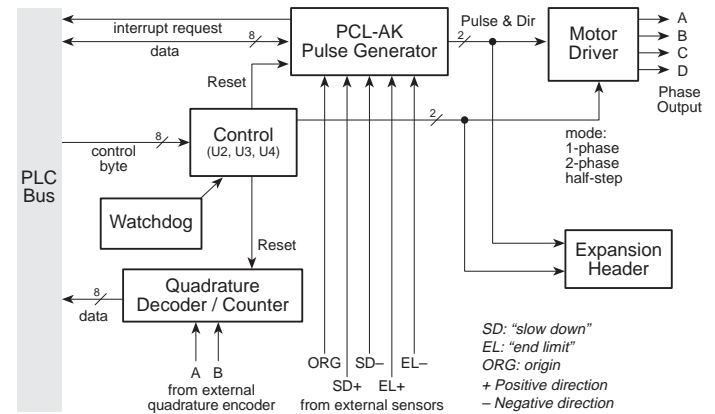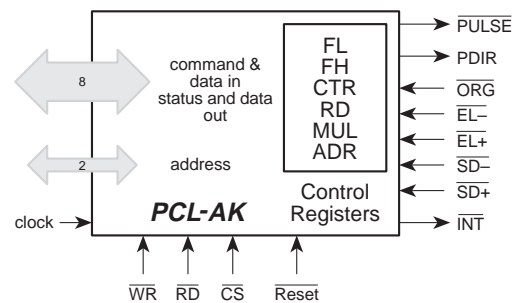

PCL-AK

Pulse output from the PCL-AK is bidirectional. The /PULSE signal steps a motor. The PDIR signal specifies the direction of rotation (1 means + direction, 0 means – direction).

The PCL-AK can sense external signals (such as "slow down," "end limit," and "origin") and can accelerate and decelerate betwen high and low speed settings and can generate interrupt requests on several conditions, such as end-of-operation. It can stop immediately or decelerate to a stop. The PCL-AK can generate thousands of different pulse rates.

It has three basic modes of operation:

continuous mode	The PCL-AK continues to generate pulses until told to stop or an external signal occurs.
preset mode	The PCL-AK generates pulses until its counter (preset) reaches 0 or an external signal occurs.
origin mode	The PCL-AK generates pulses until an "origin" pulse occurs.

This diagram shows the programmer's view of the PCL-AK.

Reg.	Bits	Meaning
CTR	18	Down-counter, which gives the number of pulses to generate. This register is readable.
FL	13	Low speed register. The PCL-AK can operate at this frequency or ramp to amd from this frequency.
FH	13	High speed register. The PCL-AK can operate at this frequency or ramp to and from this frequency.
ADR	10	Acceleration / deceleration rate register.
RD	16	Ramp-down point register. The ramp-down point is the number of pulses before end-of-count at which the PCL-AK will start ramping down from high speed to low speed. The register is readable.
MUL	10	Multiplier register. This register interacts with FL and FH to give various pulse rates.

Communicating with the PCL-AK

You tell the PCL-AK what to do by (A) writing to its command buffer and (B) writing values to its control registers. You find out what it's doing by reading the status register or a control register. Only two registers are readable: the counter and ramp-down point register.

You can issue a hard reset to the PCL-AK by pulsing the /RESET line. This resets internal registers. A soft reset (given as a command) does not change internal registers.

Status bits are available at PCL-AK addresses 0 and 3.

Motor Driver

The motor driver (UCN5804) receives two pulse signals from the PCL-AK. One signal, /PULSE, steps the motor. The other, PDIR, specifies the motor rotation (1 = forward, 0 = reverse).

The driver receives two mode signals from the control register:

Bit 7	Bit 6	Mode selected
0	0	Two-phase
0	1	Half-step
1	0	Single-phase (or wave)
1	1	undefined. (Do not use this.)

The meaning of these modes lies in how the driver generates the phase signals A, B, C, and D.


The top line of each sequence (in the above illustration) indicates the state of the driver at power-up. The 0s in the illustration indicate that the driver line is ON, that is, sinking current. The phase lines are connected to the motor's windings thus:
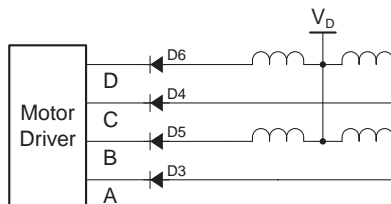
Driver Power

To select a motor driver voltage, you must consider the various losses in the driver circuit, including the collector/emitter voltage and the voltage of the blocking diode.
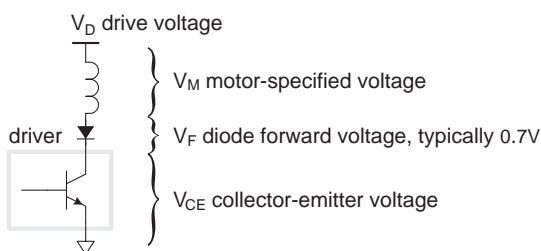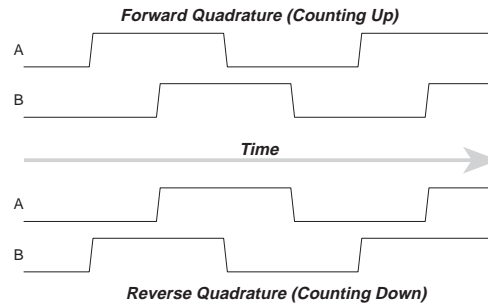

A 5V, 1A motor would require

$$V_D = V_M + V_{CE} + V_F$$
$$V_D = 5V + 1.1V + 0.7V$$
$$V_D = 6.8V$$

Quadrature Decoder / Counter

The HCTL-2016 is a 16-bit quadrature decoder and counter. Its two lines A and B accept two quadrature encoded signals, that is two square waves 90° out of phase. The order in which these signals make transitions determines the direction, up or down.

There are four states of lines A and B. The counter counts up or down depending on the state transitions.

The maximum reliable counting frequency is 3 MHz. You can read the counter as two successive bytes.

Control Register

The control register is an 8-bit write-only latch that controls operations of the SMC.

Each bit in the register has the following meaning (bit 0 is the least significant bit):
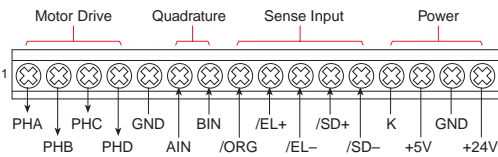
Bit	Name	Meaning
0	RESCNT	Reset quadrature decoder/counter. Low means reaset.
1	RESCTL	Reset the PCL-AK. Low means reset.
2	LED	Turn LED on or off. Low means ON.
3	SEL0	Local address line.
4	SEL1	Local address line.
5	DRVOE	Enable Motor Driver Output. Low means ON.
6	HSTEP	Half-step mode for motor driver when this bit is 1 and bit 7 is 0.
7	WAVE	Single-phase mode for motor driver when this bit is 1 and bit 6 is 0. Two phase mode when this bit is 0 and bit 6 is 0.

The select lines SEL0 and SEL1 have very specific meaning. They are connected to the two address lines of the PCL-AK. SEL0 is also connected to the quadrature decoder/counter. Coupled with PAL logic, these select lines allow you to read and write to the PCL-AK and to read the 16-bit counter value.

External Connection

Signals reach the external world on headers H5 and H6. H5 is a 14-pin header. H6 (next page) is a 16-position terminal block.

H6

Motor Drive   Quadrature   Sense Input   Power

PHA   PHC   GND   BIN   /EL+   /SD+   K   GND

PHB   PHD   AIN   /ORG   /EL–   /SD–   +5V   +24V

- **PHA, PHB, PHC, PHD**

  Open-collector motor control outputs, connecting to motor phase lines. They can sink up to 1A.

- **AIN, BIN**

  TTL-compatible quadrature-encoded inputs.

- **/ORG**

  Active-low origin pulse. Readable in the PCL-AK (address 0) status bits.

- **/EL+, /EL–**

  Active-low end-limit, one for the + direction, another for the – direction. Readable in the PCL-AK (address 0) status bits.

- **/SD+, /SD–**

  Active-low "slow-down" inputs, one for the + direction, another for the – direction. Readable in the PCL-AK (address 3) status bits.

- **K**

  Driver chip protection. Connect this to your motor's voltage source.

- **+24V**

  Unregulated PLCBus power. Though nominally 24V, this can be anywhere from 9–30VDC. You can use this as the motor supply voltage of your power supply can handle the current requirements.

- **+5V**

  Regulated PLCBus power. A poor source for motor power, but can be used to power external logic.

- **GND**

  PLCBus ground, common to your entire system. Your motor's power supply ground should be connected here.

H5

H5 provides additional connection points for motor control signals, power and ground, power failure, and watchdog signals.
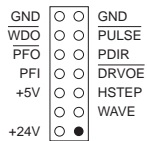
- **/PULSE**

  A low-going pulse in this line signals a one-step move to the motor driver. (TTL)

- **PDIR**

  Indicates in which direction the motoro is to move. A high level means movement in the + direction. A low level means movement in the – direction.

- **/DRVOE**

  When low, enables motor driver outputs. (TTL)

- **WAVE**

  Coupled with HSTEP, this determins the operation of the motor driver: single-phase, two-phase, or half-step. (TTL)

- **HSTEP**

  Coupled with WAVE, this determines the operation of the motor driver: single-phase, two-phase, half-step. (TTL)

- **/WDO**

  Active low, open-collector watchdog output line. When the watchdog is enabled, this line will go low—upon a watchdog timeout—to getnerate a hard reset at the PCL-AK pulse generator.

- **PFI**

  Input to the power-fail comparator. When this line drops below ~1.25V, the /PFO line becomes active.

- **/PFO**

  Open collector power-failure indicator. This line goes low when PFI goes below ~1.25V. This line can be connected to the NMI or interrupt line on the master controller.

- **+24V**

  Unregulated PLCBus power.

- **+5V**

  Regulated PLCBus power.

- **GND**

  PLCBus ground.

Jumpers

The SMC uses one jumper, J1, and a header H4. When J1 is connected, the watchdog timer is enabled. When disconnected, the watchdog timer is disabled. The four jumper positions on H4 determine the board's PLCBus address.

How to Use an SMC Board

Generally, this is what you do:

1. Initially, send a reset command to the PLCBus.

2. Place the address of the SMC on the PLCBus. This will actually be the address of one of its components, the PCL-AK or the quadrature decoder/counter.

3. Operate the SMC. You can, for example,

   - Set the SMC control register.
   - Issue a command to the PCL-AK pulse generator.
   - Set PCL-AK parameters or read PCL-AK registers or status.
   - Reset the quadrature counter or read its value.
   - Wait for interrupt requests.

4. Following an SMC operation, you typically issue a soft reset to the PCL-AK. Refer to Z-World's Tech Note 101 for details about the PCL-AK.

There is a software library (STEP.LIB) that handles all the complex details of operating the SMC.

Addressing the board

Up to 16 SMCs may addressed on the PLCBus. Each SMC has three addressable components: the PCL-AK pulse generator and

the quadrature decoder/counter, and the control register. The address of a particular SMC is determined by jumpers on H4:

abcd1100 x0000Rxx

a = 0 if H4 pins 1 and 2 are connected, and 1 if not
b = 0 if H4 pins 3 and 4 are connected, and 1 if not
c = 0 if H4 pins 5 and 6 are connected, and 1 if not
d = 0 if H4 pins 7 and 8 are connected, and 1 if not
x = don't care
R = 0 to read or write the PCL-AK pulse generator
R = 1 to read the quadrature counter
R = 1 to write the control register

The LED (D2) will light when the SMC board is addressed.

Software keeps information for all SMCs on the PLCBus in a table, sorted by SMC address. Thus, SMC boards have logical addresses which are simply indexes into the table.

Reset States

There are many ways to reset the SMC and its components.

Power-Up Reset

On power-up, both the PCL-AK and the quadrature decoder/counter undergo a hard reset.

The control register powers-up to an unknown state, thus your application program should initialize it before using anything else on the board.

PLCBus Reset

A PLCBus reset command strobes both the PCL-AK and quadrature decoder/counter reset lines, forcing hard resets for both. The control register and motor driver are not effected by a PLCBus reset.

Watchdog Reset

The watchdog timer is a safety feature that halts the PCL-AK (and therefore, motion) in the event of a system crash. When you turn on the watchdog, your software must periodically "hit" the watchdog at least every 1.5 seconds. The quadrature counter is not reset in the event of a watchdog timeout.

Once reset this way, the PCL-AK will stay reset until your software hits the watchdog again. Connecting the jumper J1 enables the watchdog function. When it is unconnected, a watchdog reset will not occur.

PCL-AK Reset

Aside from the watchdog reset and power-up reset, there are two other ways to reset the pulse generator.

To achieve a soft reset, write a reset command to the controller. A soft reset immediately stops pulse generation and deactivates the PCL-AK's interrupt request line if it is active. The contents of PCL-AK registers are not affected.

To achieve a hard reset, drive the PCL-AK reset line low.

Quadrature Counter Reset

The quadrature counter is reset to zero on power-up.

PCL-AK Formulas

The ADR—a register with settings from 2 to 1023—governs ramping-up (acceleration) and ramping-down (deceleration) characteristics. When started in high-speed mode, the PCL-AK starts with the speed set on FL register and accelerates to reach the speed set in the FH register.

The Z-World reference clock frequency is 6 MHz. The clock period is 1/6 µs. The time it takes to accelerate or decelerate is

$$T_{RAMP} = (FH - FL) \times ADR / 6, \quad \text{in microseconds.}$$

The relationship between acceleration and the ADR is this:

$$accel = \frac{CLOCK}{ADR} \qquad [\text{pulses} / \text{second}^2]$$

The relationship between the value of a speed register (FL or FH) and actual output frequency is

$$\text{freq}_{HIGH} = \frac{FH}{8192} \times \frac{CLOCK}{MUL} \qquad [\text{pulses} / \text{sec}]$$

$$\text{freq}_{LOW} = \frac{FL}{8192} \times \frac{CLOCK}{MUL} \qquad [\text{pulses} / \text{sec}]$$

The term MUL is the value of the multiplier register. It can be from 2 to 1023.

Referring to the picture below, the number of pulses output during T_{DEC} is represented by the area of the shaded trapezoid:
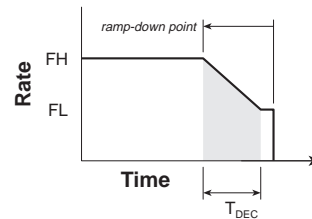
$$P_{DEC} = \frac{(\text{freq}_{HIGH} + \text{freq}_{LOW}) \times T_{DEC}}{2} \qquad [\text{pulses}]$$

or

$$P_{DEC} = \frac{(FH^2 - FL^2) \times ADR}{16384 \times MUL} \qquad [\text{pulses}]$$

The speed registers (FH and FL) have values from 1 to 8191. The reference clock (on the CLOCK pin) is divided by the variable frequency divider and multiplied by the frequency multiplier then output to /PULSE. The actual pulse frequency is given here again:

$$\text{freq} = \frac{F_X}{8192} \times \frac{CLOCK}{MUL} \qquad [\text{pulses} / \text{sec}]$$

$$= F_X \times factor \qquad [\text{pulses} / \text{sec}]$$

When *factor* = 1, output pulse frequency is the same as the contents of the speed register (either FL or FH). With Z-World's 6 MHz reference clock, MUL = 732 (actually, 732.421875 rounded off) gives a factor close to 1, but not exactly.

Specifications

Board Size	$2.835 \times 4.0 \times 0.58$
Operating Temp	–40°C to +70°C
Humidity	5% to 95% non-condensing
Power	24VDC, 40 mA
Provides	One-axis stepper motor control rated at 35V and 1.25A per phase in full step mode, and 1 amp per phase in half-step mode.

XP810

An XP8100 ... adds up to 32 digital I/O lines to yo... ...nes can be inputs or outputs, depending ... order.

The XP810... ...the factory in three standard config...

- XP8100 ... ...uts.
- XP8110 ...
- XP8120 ...

You can ge... ...w (and others) by special order:

- 8 inputs ...
- 8 output...

Shown belo... ...X

Each bank consists of two groups of 8 lines. If any of the 8 lines in a group are high-current outputs, all the lines in the group must be high-current outputs, since the lines use the same driver chip. If you are not using high-current driver chips in that group, you can mix inputs and outputs by special order and the outputs will be TTL- and CMOS-compatible.

These are the standard configurations.

Product	H1 (0–7)	H2 (8–15)	H3 (16–23)	H4 (24–31)
XP8100	8 outputs	8 outputs	8 inputs	8 inputs
XP8110	8 inputs	8 inputs	8 inputs	8 inputs
XP8120	8 outputs	8 outputs	8 outputs	8 outputs

Three Z-World FWT modules can be used with the IO32.

|	
FWT38.	Quick-connect mass termination, 3.81 mm centers, 16 data lines.
FWT50	Screw terminals, 5 mm centers, 16 data lines.
FWT-Opto.	Quick-connect mass termination, 3.81 mm centers, 16 data lines with optical isolation.

There are two positions, one for each bank, where you can place an FWT module.
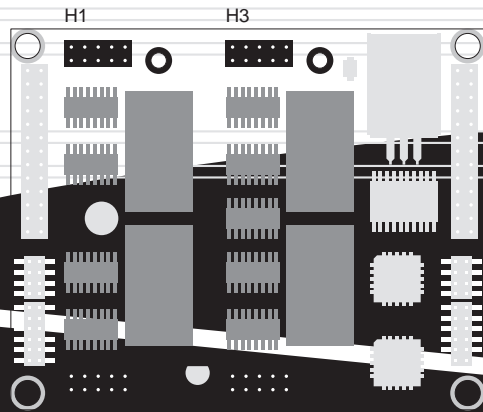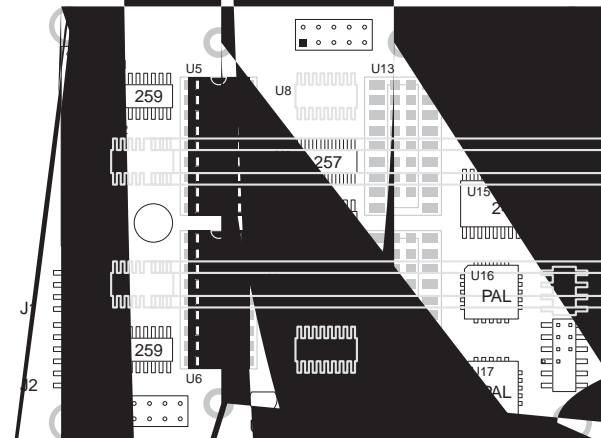
The XP8100 series also has two FWT (field-wiring terminal) modules.

Setting Board Addresses

Jumpers placed J4 on configure the PLCBus address. The board address therefore may ...

J4

— Address ...
— Address ...
— Address ...
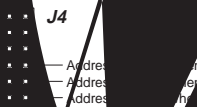
The IO32 receives power from your controller over the +V line (normally by PLCBus. An on-board regulator supplies XIO32 current consumption ... mA ... power required ... from 12 V supply ... for a 24 V supply.

I/O Config

The 32 lines are in two banks of 16 lines. Headers H1 and H2 support Bank A. Headers H3 and H4 support Bank ...

Protected Digital Inputs

Protected digital inputs can operate continuously from –20V to +24V DC with a logic threshold at 2.5V. (An input is a '0' if its voltage is below 2.5V. It is a '1' if its voltage is above 2.5V.

257
/G

139

Each input is protected against spikes in the range ±48V by a low-pass filter and a diode in the input buffer ('257 chip). The filters have a time constant of 220 µs (equivalent to 4.5 kHz). The resistors in the filters also limit current.

Inputs may be configured with pull-up or pull-down in groups of fours and eights. Use jumpers J2 and J4. Optically isolated input lines must be have pull-up resistors.
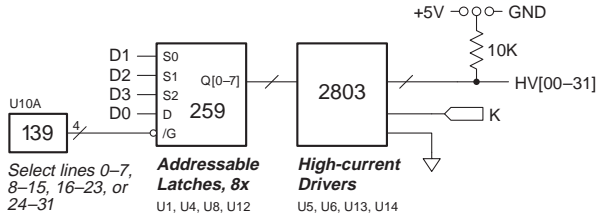
Outputs

The XP8100 high-current outputs normally have "sinking" drivers. The sinking drivers (2803s) are ra*ted at* a maximum output of 48V at 500 mA per individual output (when only one output is active). You can get sourcing drivers (2985s) by special order. Each driver chip can, and should, be connected to a "K" line to prevent inductive kickback current from damaging the drivers.

When all sinking outputs are on simultaneously, thermal limits restrict the current to 75 mA per output. If the temperature exceeds 50°C, derate power dissipation by 55°C per Watt.

Jumpers J1 and J3 route the K and GND lines to the drivers, according to whether you have sinking or sourcing drivers.

Jumpers

There are 4 locations for jumper blocks. Not all of the jumper blocks may be installed on your particular model.

XP8100 Jumpers (16 Inputs, 16 Outputs)

J1 Bank A outputs 0–15, sinking vs. sourcing configuration

J2 Bank B inputs 0–7, pull-up/down resistors

J4 Bank B inputs 8–15, pull-up/down resistors and board address

XP8110 Jumpers (32 Inputs)

J2 Bank A inputs 0–7 and bank B inputs 0–7, pull-up/down resistors

J4 Bank A inputs 8–15, bank B inputs 8–15, pull-up/down resistors, and board address

XP8120 Jumpers (32 Outputs)

J1 Bank A outputs 0–15, sinking vs. sourcing configuration

J3 Bank B outputs 0–15, sinking vs. sourcing configuration

J4 Board address

TTL- and CMOS-Compatible Outputs

If you want TTL- or CMOS-compatible outputs, Z-World will install the appropriate connections required. You have to request it. With TTL/CMOS outputs, input and output channels may be configured independently in any combination.

Specifications

Inputs

Input voltage range	–20V to +24V continuous. Protected against spikes in ±48V range.
Logic threshold	2.5V
Resistors	User-settable, pull up or pull down, in groups of four and eight
Input protection	low-pass filter, 22K current-limiting series resistor, input-protection diode
Low-pass filter	220 μs
Input-leakage current	5 mA

Outputs

Default	Sinking drivers (2803)
Maximum current	500 mA single channel
Non-inductive voltage	+5V to +48V
Inductive voltage	+5V to +30V
Switching response	1 μs
Leakage current	100 mA max

The UDN2985 is rated at 30V and 250 mA for an individual output at 25°C.

FWT50

Total I/O Channels	16
Pitch	5 mm
Maximum Wire	24–12 AWG
Quick Disconnect	No
Wire Orientation	Side

FWT38

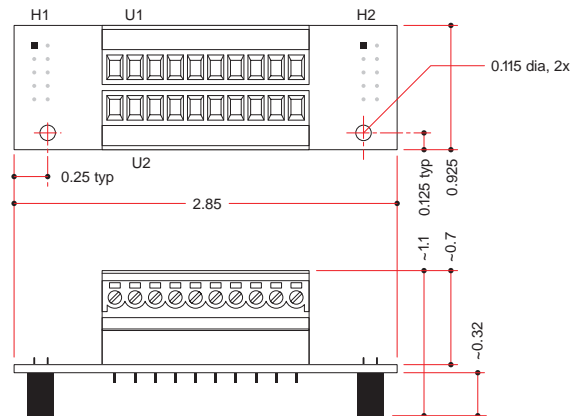|	
Total I/O Channels	16
Pitch	3.81 mm (0.15")
Maximum Wire	28–16 AWG
Quick Disconnect	*Yes*
*W*ire Orientation	Top

FWT-Opto

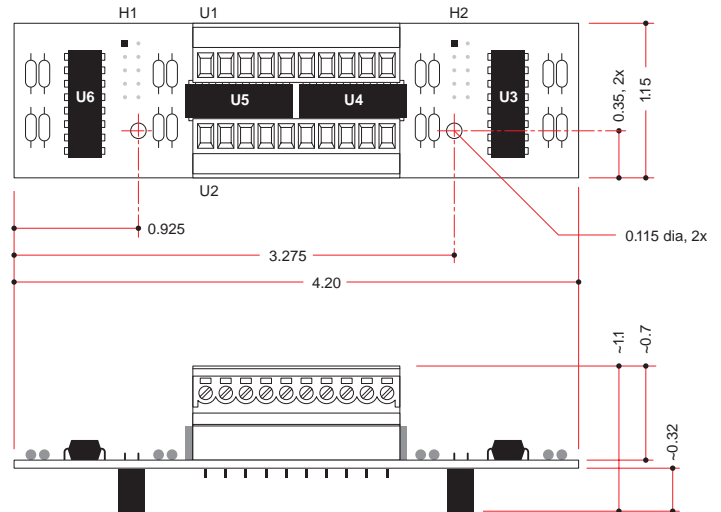|	
Total I/O Channels	16, optically isolated (input channels only)
Pitch	3.81 mm (0.15")
Maximum Wire	28–16 AWG
Quick Disconnect	Yes
Wire Orientation	Top
Input Protection	5 kV *RMS* between input and output
AC Input Response	–40V to +40V

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FWT-50

FWT-38

FWT-OPTO