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Ocean Optics Inc. First in Photonics™
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PC2000-PC/104 Data Sheet

Description

The Ocean Optics OEM PC2000-PC/104 Spectrometer includes the linear CCD-array optical bench, plus the digital interface necessary to function on a PC/104 bus. The result is a compact, flexible system with no moving parts that's easily integrated as an OEM component.

The PC2000-PC/104 spectrometer is a unique combination of technologies providing users with both an unusually high spectral response and good optical resolution in a single package. The electronics have been designed for considerable flexibility in connecting to various PC2000-PC/104 series modules as well as external interfaces. The PC2000-PC/104 can be directly coupled to as many as seven "slave" spectrometer channels of various designs. The information included in this guide provides detailed instructions on the connection and operation of the PC2000-PC/104.

The detector used in the PC2000-PC/104 spectrometer is a high-sensitivity 2048-element CCD array from Sony, product number ILX511. (For complete details on this detector, visit Sony's web site at http://www.sel.sony.com/semi/PDF/ILX511.pdf. However, Ocean Optics applies a coating to all ILX511 detectors, so the optical sensitivity could vary from that specified in the Sony datasheet).

Features

- High sensitivity of up to 90 photons/counts
- An optical resolution of 3 pixels (FWHM)
- A wide variety of optics available
  - 14 gratings
  - 6 slit widths
  - 3 detector coatings
  - 6 optical filters
- Integration times from 2 to >30,000 milliseconds
- Modular design allows up to 7 slave spectrometer channels to operate from one master channel
- 2MHz, 12 bit A/D, ± ½ bit accuracy
- Supports free-running an 3 external trigger modes
- Digital Interface
- Memory mapped registers
- Interrupt driven
- 2,048 deep FIFOs for on board storage
- Can acquire spectra simultaneously from all 8 channels at reduced pixel density
- Strobe signals for external synchronization

Specifications

Specifications	Criteria
Absolute Maximum Ratings:	
V_{CC}	+ 5.5 VDC
Voltage on any pin	Vcc + 0.2 VDC
Physical Specifications:	
Physical Dimensions (no enclosure)	4.05 (W) x 3.78 (L) x 0.70 (H) inches
Weight	200 g
Power:	
Power requirement (master)	250 mA at +5 VDC
Supply voltage	4.5 – 5.5 V
Power-up time	3 msec
Spectrometer:	
Design	Asymmetric crossed Czerny-Turner
Focal length (input)	42mm
Focal length (output)	68mm (75, 83 and 90 mm focal lengths are also available)
Input Fiber Connector	SMA 905
Gratings	14 different gratings
Entrance Slit	5, 10, 25, 50, 100, or 200 µm slits. (Slits are optional. In the absence of a slit, the fiber acts as the entrance slit.)
Detector	Sony ILX511 CCD
Filters	Selection of Long Pass Filters to eliminate 2nd order (optional)
Spectroscopic:	
Integration Time	3 – >30,000 msec
Dynamic Range	2 x 10^8
Signal-to-Noise	250:1 single acquisition
Readout Noise (single dark spectrum)	3.5 counts RMS, 20 counts peak-to-peak
Resolution (FWHM)	0.03 – 10.0 nm varies by configuration
Stray Light	<0.05% at 600 nm; <0.10% at 435 nm
Spectrometer Channels	8 (master plus 7 slaves)
Environmental Conditions:	
Temperature	-30° to +70° C Storage & -10° to +60° C Operation
Humidity	0% - 90% noncondensing

Electrical Pinouts

J2 Electrical Connector

Pin	I/O	Function
1	I	Analog Channel 1
2	I	Analog Channel 2
3	I	Analog Channel 3
4	I	Analog Channel 4
5	I	Analog Channel 5
6	I	Analog Channel 6
7	I	Analog Channel 7
8		Vcc
9	O	CCD Temperature
10		Vcc
11		Gnd
12		N/C
13		Gnd

Pin	I/O	Function
14		Gnd
15	N/C	Reserved – D2
16	N/C	Reserved – D0
17	O	Continuous Strobe
18	I	External Hardware Trigger
19	O	Array Clock Output
20	O	Lamp Enable - S0
21	O	Single Strobe
22	I	External Sync Input
23	O	Read Out Gate
24	N/C	Reserved – D1
25	N/C	Reserved – D3
26	I	Software Trigger

J2 on PC104 is Samtec #STMM-113-02-S-D-RA, the mating part is a ribbon cable #TCSD-13-D-(length)-01--other mating options are SQT,SQW,ESQT,TLE,SMM,MMS

Pin Function Description

Function	Description
Analog Channel 0 - 7	The analog signals that correspond to the output from the 8 spectrometer channels. Inputs for channels 1-7 are available on J1.
V_{CC}	The positive supply voltage +5VDC.
GND	The ground (supply voltage return) or case ground.
Lamp Enable	Software-controlled TTL signal commonly used for activation of Light Sources
Software Trigger	Active high TTL input signal used to trigger the acquisition system in the External Software Trigger mode.
Single Strobe	TTL output signal used to pulse a strobe that is high at the start of each integration period.
Continuous Strobe	TTL output signal used to pulse a strobe that is divided down from the Master Clock signal.
External Hardware Trigger	TTL trigger signal (rising edge trigger input) used in External Hardware Trigger mode.
External Sync Input Trigger	TTL signal used to define the integration time (time between rising edges) when using the External Synchronization Trigger mode.
CCD Temperature	Analog signal generated from an LM35 mounted in close proximity to the CCD. The analog output is 10mv/C.

Interface Information

Pixel Definition

A series of pixels in the beginning of the scan have been covered with an opaque material to compensate for thermal induced drift of the baseline signal. As the PC2000-PC/104 warms up, the baseline signal will shift slowly downward a few counts depending on the external environment. (Temperature-regulated units do not exhibit this shift.) The baseline signal is set between 50 and 100 counts at the time of manufacture. If the baseline signal is manually adjusted, it should be left high enough to allow for system drift. The following is a description of all of the pixels:

Pixel	Description
0–1	Not usable
2–24	Optical black pixels
24–25	Transition pixels
26–2674	Optical active pixels

It is important to note that Ocean Optics A/D products only digitize the first 2048 pixels, as they all have a 2048 x 16 FIFO buffer.

Analog Section

The PC2000-PC/104 is capable of supporting the output of up to 8 spectrometer channels (master channel plus 7 slave channels). The spectrometer channel is determined by switch SW2. Within a stack, there should be only one spectrometer on any given channel. The master spectrometer is hardwired to the master channel (channel 0). Each spectrometer generates an analog signal (-2.5 - +2.5V), which corresponds to the input spectra.

Clock Signals

Master Clock

The frequency of this clock is set via software. The A/D rate is one-half that of the Master Clock. The maximum rate for the Master Clock is 4MHz, which equates to an A/D rate of 2 MHz. A recommended minimum frequency is 100 kHz.

Integration Clock

The frequency of this clock is set via software. The period for the integration time clock should be longer than 4100 master clock periods in order to read the entire array. This equates to 1.1ms.

Strobe Signals

Single Strobe

The Single Strobe signal is a TTL HIGH pulse that occurs at the start of each integration period. This pulse occurs 2 master clock cycles after the start of the integration period. The pulse is not generated unless The Lamp Enable (S0) signal is set (Digital 1-TTL HIGH) in software.

Continuous Strobe

The Continuous Strobe signal is a pulse-train (50% duty cycle) whose frequency is determined by software.

Synchronizing Strobe Events

For some applications it is necessary to view pulsed sources. If the application requires more than one pulse per integration period, exercise care to insure a stable signal. The integration time must be set so that an equal number of strobe events occurs during any given integration period. This synchronization only occurs when the integration period is a multiple of a power of 2, since the strobe signal is the master clock divided by a power of 2.

Triggering Modes

The PC2000-PC/104 supports four triggering modes, which are defined by the state of the software controlled S0 and S1. Details of each triggering mode are discussed below.

Mode	S1	S0
Normal	0	X
Software Trigger	0	X
Ext Synchronization	1	0
Ext Hardware Trigger	1	1

Normal (S1:S0 = 0:X)

In this mode, the PC2000-PC/104 uses the user-supplied integration clock (DB25: pin 23) and continuously scans the CCD array.

External Software Trigger (S1:S0 = 0:X)

In this mode, the PC2000-PC/104 uses the normal integration clock. Since this mode is under software control its functionality can be software defined. In this mode, Ocean Optics software, waits until the Software Trigger Input (D3) line goes HIGH before it acquires an acquisition. The amount of delay between the trigger pulse and when a spectrum is acquired is indeterminate because the delay is dependent upon (1) how fast the software polls the D3 line and recognizes it is HIGH and (2) the amount of time until the start of the next integration period. The integration time is under user control in this mode. This mode must be implemented in the software that controls the data acquisition.

External Synchronization (S1:S0 = 1:0)

In this mode, the effective integration time is the time between rising edges of the signal applied to the External Synchronization pin (J2:Pin 22). This mode is useful for synchronizing the integration time to an external clock source.

External Hardware Trigger (S1:S0 = 1:1)

In this mode, the PC2000-PC/104 uses an internally generated integration clock that is triggered by the rising edge of the External Hardware Trigger signal (J2:pin 18). On the rising edge of this signal, the internal logic resets the CCD array, integrates for 2.1ms and then clocks out the array.

CCD Detector Temperature

Also available is an optional temperature sensor, which when included is located directly under the detector. The output of this signal is fed to H2: pin 6. The typical error of the sensor is ± ^{o}C around 25^{o}C. The output is calibrated directly in ^{o}C with a scale factor of 10 mV/^{o}C.

Software Interface

Overview

The PC2000-PC104 employ a memory mapped set of registers, which control all of the functionality. The register definition is shown in ***Table 1. PC2000-PC104 Programming Registers***. Communications with the spectrometer are through a base address, which is defined by switch settings. *Software Trigger Port (base + 5) Bit Description*

Performing an 8-bit read from this port will provide the state of the Software Trigger input on the D3 line (i.e., Read Value & 0x04 to determine Trigger Input line state).

Read Spectral Data (base + 6) Bit Description

Performing a 16-bit read from this port will return one spectral data point. To obtain full spectra perform 2048 reads after interrupt initiation. Raw data format is signed—invert bit 11 to convert to unsigned (i.e. Data Value XOR’ed with 0x0800).

Channel Rotation Port (base + 7) Bit Description

Byte wide writes to this port activates or deactivates the rotator. If activated, the value written determines the number of channels rotated through.

Value Written	Function
0	Disables channel rotation
9 (0x09)	Rotates channels 0 and 1
10 (0x0A)	Rotates channels 0 through 2
11 (0x0B)	Rotates channels 0 through 3
12 (0x0C)	Rotates channels 0 through 4
13 (0x0D)	Rotates channels 0 through 5
14 (0x0E)	Rotates channels 0 through 6
15 (0x0F)	Rotates channels 0 through 7

Table 2. Switch Settings for Base Address and IRQ illustrates how to configure the switch settings for the desired base address. Once a spectra is acquired and ready to be readout, the spectrometer generates an IRQ. The specific IRQ is defined by switch setting as listed in *IRQ Interrupt Request Settings*.

Table 1. PC2000-PC104 Programming Registers

Port Address	PC2000-PC104 Register Description
base + 0	Master Clock Counter Port (base frequency is 8 MHz)
base + 1	Continuous Strobe Counter Port (base frequency is 976 Hz)
base + 2	Integration Clock Counter port (base frequency is 976 Hz)
base + 3	N/A
base + 4	Command port (output only)
base + 5	Software Trigger Digital Input port (bit 3 only)
base + 6	Read Spectral Data (WORD Access)
base + 7	Channel rotation command port

Counter Ports (Base – Base +2) Description

Output frequency of counter is base frequency divided by the 16bit value written to this port. Limits for the various counters along with the corresponding counter value are provided below.

Counter	Min	Typical	Max
Master Clock		4Mhz→ 2	4Mhz→ 2
Continuous Strobe	2.048ms period → 2		
Integration Clock	3.072ms period → 3		

Command Port (Base +4) Bit Description

Writes to this 8-bit port control the spectrometer's functionality.

Bit	Function
7	MUX address bit 2
6	Enable board interrupt (1=enabled)
5	Master reset to clear FIFO (1=reset)
4	MUX address bit 1
3	MUX address bit 0
2	Spectrometer mode control S1
1	Spectrometer mode control S0 Multiplexed as Strobe enable (1=enabled)
0	Read enable (1=enabled)

Software Trigger Port (base + 5) Bit Description

Performing an 8-bit read from this port will provide the state of the Software Trigger input on the D3 line (i.e., Read Value & 0x04 to determine Trigger Input line state).

Read Spectral Data (base + 6) Bit Description

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13 (0x0D)	Rotates channels 0 through 5
14 (0x0E)	Rotates channels 0 through 6
15 (0x0F)	Rotates channels 0 through 7

Table 2. Switch Settings for Base Address and IRQ

Base Address Settings

Switches 1 – 6 of SW1 determine the base address, which is the weighted sum of these switches. The switch position is negative logic (i.e. 1 is off). The factory default is 0x300 hex or 768 decimal.

Switch #	Address line	Value (hex)	Value (decimal)	Switch setting for 300 hex	Switch position
1	A4	10h	16	on	0
2	A5	20h	32	on	0
3	A6	40h	64	on	0
4	A7	80h	128	on	0
5	A8	100h	256	off	1
6	A9	200h	512	off	1

IRQ Interrupt Request Settings

The following matrix defines the different Interrupt Request settings by switch positions 7, 8, and 9. In the default setting, the IRQ is set to 7. Combinations for IRQ settings follow.

Switch Settings		
#7	#8	IRQ
0	0	3
1	0	4
0	1	5
1	1	7 (Default)

1 indicates a switch in the ON position

Counters

The PC2000-PC104 implemented the core of an 82C54 programmable timer in the FPGA to implement the required clock signals. Refer to this data sheet for more detailed information. This implementation requires no control word to be written to the counter. These timers use the equivalent of control mode 3 (50% duty cycle) and the counters are always enabled. The base frequency for each of the timers is shown in Table 1.

Programming

Pseudo-code programming for the PC2000-PC104 is provided in *PC2000-PC/104 Programming Sequence*.

PC2000-PC/104 Programming Sequence

This technical document describes the programming procedures necessary to control and PC2000-PC104 spectrometer. This setup is functionally identical to the S2000 spectrometer and ADC1000 ISA card. The pseudo-code examples below use the following definitions:

(Note: all numbers starting with "0x" are in hexidecimal.)

- `source code is in this font`
  comments are in this font
- `outport_byte(baseadd+1,0x13)` -- outputs one byte of data to the specified port, represented as an offset from the base address
- `outport_word(baseadd+1,0xffff)` -- outputs one word of data to the specified port, represented as an offset from the base address
- `inport_byte(baseadd+3)` -- inputs one byte of data from the specified port, represented as an offset from the base address
- `inport_word(baseadd+5)` -- inputs two bytes (one 16-bit word) of data from the specified port, represented as an offset from the base address
- Variables:
  `baseadd` -- the base address in decimal, 16-bit integer
  `dsf` -- digital sample frequency, or A/D conversion frequency, 16-bit integer
  `fdc` -- number of flashes per scan, 16-bit integer
  `cmd` -- command to be sent to A/D card, 8-bit (unsigned) integer
  `average` -- number of scans to average
  `oldvect` -- stored interrupt vector
  `current_channel` -- active spectrometer channel
  `indata` -- data read from the A/D card
  `irq` -- the interrupt number (interrupt request) of the ADC500/ADC1000/PC1000
  `ihandler` -- the interrupt handler function

- Operators:
  >> bit shift operator
  == equal comparison operator
  & bit-wise AND operator
  ^ bit-wise XOR operator
  | bit-wise OR operator

One internal pseudo-code function is used -- `CheckTriggerMode()`. This function checks the trigger mode and sets the appropriate spectrometer mode control bits (S0 and S1) in the command sent to the ADC500/ADC1000 control port. The psuedo-code for this function is:

```
if trigger_mode = external_synchronization then cmd = cmd | 0x04
if trigger_mode = external_hardware_trigger then cmd = cmd | 0x06
if trigger_mode = software_trigger then cmd = cmd & 0xf9
if trigger_mode = no_trigger then cmd = cmd & 0xf9
```

Step 1: Initialize A/D Functions

`outport_word(baseadd+1,0x0010)`	Loads counter 1, which is set to a ~10 msec period.
`outport_word(baseadd,0x0002)`	Loads counter 0, which is set to 4Mhz
`cmd = 0x20`	master reset
`CheckTriggerMode()`	check the external trigger mode
`outport_byte(baseadd+4,cmd)`	send command to ADC500/ADC1000
`delay(10)`	delay for 10 msec to allow "settling"
`cmd = 0x00`	cancel reset and leave disabled
`CheckTriggerMode()`	check the external trigger mode
`outport_byte(baseadd+4,cmd)`	send command to ADC500/ADC1000

This function initializes the A/D card. First, the countinuous strobe counter (1) is loaded with a divisor so that the resulting period is ~10 msec. Next the Master Clock counter is initialized to the fasted possible value (4MHz). The A/D card is reset and disabled.

Step 2: Setup Integration Time

`if dsf < 3 then dsf = 3`	make sure integration time is not below the allowable minimum
`outport_word(baseadd+2, dsf)`	load counter 2, which defines the integration time
`if dsf < 25 then delay(25) else delay(12*dsf/10)`	delay to allow the previous cycle to complete before we start the next integration cycle

This function sets the integration time of the spectrometer. There must be a delay after this setting to allow the previous integration period to complete before the new one begins.

Step 3: Install Your Interrupt Vector

Consult your hardware documentation to determine how to do this correctly. Below is a sample C function, which installs the interrupt service routine using Borland C 4.0 in a DOS environment.

```
disable()
```
disable interrupts during this change

```
oldvect = getvect(irq + 8)
```
save the old interrupt vector for the IRQ

```
setvect(irq + 8, ihandler)
```
set the interrupt vector to be the address of your interrupt handler

```
if irq == 2 then outport_byte(0x21,
inport_byte(0x21) & 0xfb)
```
unmask the correct IRQ

```
if irq == 3 then outport_byte(0x21,
inport_byte(0x21) & 0xf7)
```
unmask the correct IRQ

```
if irq == 5 then outport_byte(0x21,
inport_byte(0x21) & 0xdf)
```
unmask the correct IRQ

```
if irq == 7 then outport_byte(0x21,
inport_byte(0x21) & 0x7f)
```
unmask the correct IRQ

```
enable()
```
reenable interrupts once done changing

After disabling interrupts, we store the old interrupt vector for the IRQ in oldvect. We then set the new interrupt vector to a function called ihandler (described below). Then, we enable a specific interrupt by changing the interrupt mask.

Step 4: Trigger a Data Acquisition Cycle

```
port = baseadd + 4
```
identify the PC2000-PC104 control port

```
cmd = cmd & 0xe7
```
clear the channel bits

```
if current_channel between Master
and Slave3 then
cmd = cmd | current_channel << 3
cmd = cmd & 0x7f
else
cmd = cmd | current_channel << 3
cmd = cmd | 0x80
end if
```
set the A/D MUX channel. If the MUX channel is between 0 and 3, the highest order bit for the MUX selection is set to 0, or else it is set to 1.

```
CheckTriggerMode()
```
check the external trigger mode

```
outport_byte(port,cmd)
```
set command to PC2000-PC104

```
cmd = cmd & 0xbe
```
disable triggers and interrupts

```
cmd = cmd | 0x20
```
reset the FIFO buffer

```
CheckTriggerMode()
```
check the external trigger mode

```
outport_byte(port,cmd)
```
set command to PC2000-PC104

```
cmd = cmd & 0xdf
```
cancel the reset

```
CheckTriggerMode()
```
check the external trigger mode

`outport_byte(port,cmd)`	set command to PC2000-PC104
`cmd = cmd | 0x41`	enable interrupts and triggers
`if external software triggering then while inport_byte(baseadd + 5) & 8) == 0 wait on this line`	if you are external triggering, constantly query the digital input on pin 26 of the 26 pin connector to check for it to go high (+5VDC)
`CheckTriggerMode()`	check the external trigger mode
`if not scanning a dark spectrum or using external triggering then cmd = cmd | 2`	if you are scanning a dark spectrum or using an external trigger mode do not turn on the flash
`outport_byte(port,cmd)`	set command to PC2000-PC104

This function does a lot. First, it identifies the PC2000-PC104 control port as baseadd + 4. It then clears the MUX address of the A/D, sets the MUX address of the A/D, turns off the flash-during-scan, resets the FIFO buffer, cancels the FIFO reset, enables the triggers and interrupt (**this is VERY IMPORTANT, as it is what makes it all work**), and waits for an external software trigger on pin 8 of the DSUB15 connector, if requested. The function then triggers a scan.

Step 5: Service the Interrupt

When a scan is completed, your program is notified by an interrupt. You MUST service this interrupt IMMEDIATELY. The interrupt service routine (ISR) must be as short as possible. Do as little processing as possible in the ISR. The following is our ISR.

`cmd = cmd & 0xbe`	turn interrupts and triggers off
`CheckTriggerMode()`	check the external trigger mode
`outport_byte(baseadd + 4,cmd)`	stop the acquisition
`enable()`	restart interrupts
`for i = 0 to 2047 indata(i) = (inport_word(baseadd + 6) ^ 0x0800) & 0x0fff next i`	read 2048 data points from the FIFO buffer, convert to unsigned values and mask off upper 4 bits (0-4095 value)
`cmd = cmd & 0xbe`	turn interrupts and triggers off
`cmd = cmd | 0x20`	reset the A/D cards FIFO
`CheckTriggerMode()`	check the external trigger mode
`outport_byte(baseadd + 4,cmd)`	issue the command
`cmd = cmd & 0xdf`	cancel the reset
`CheckTriggerMode()`	check the external trigger mode
`outport_byte(baseadd + 4,cmd)`	issue the command
`outport_byte(0x20,0x20)`	send a non-specific EOI (end of interrupt) to the 8259 interrupt controller chip

Many actions happen at interrupt time. First, we disable the PC2000-PC104 so that it does not continue to scan. Then, we read the data from the FIFO. After the data is read, the spectrometer is reset. You must be sure to tell the computer you have serviced the interrupt. That is done by issuing a non-specific end-of-interrupt (EOI) to the 8259 interrupt controller chip by outport_byte(0x20,0x20). At the end of this function, if you wish to immediately capture another scan, you can call the function in *Step 4: Trigger a Data Acquisition Cycle* after the outport_byte(0x20,0x20) function call.

Step 6: Remove the Interrupt Handler

When you are done with the driver communicating with the spectrometer, you must return the interrupt vector to its original state. Again, this function will depend on your operating environment, and we provide a sample in Borland C 4.0 for DOS.

`Disable()`	disable interrupts during this change
`if irq == 2 then outport_byte(0x21, inport_byte(0x21) | 0x04)`	mask the correct IRQ
`if irq == 3 then outport_byte(0x21, inport_byte(0x21) | 0x08)`	mask the correct IRQ
`if irq == 5 then outport_byte(0x21, inport_byte(0x21) | 0x20)`	mask the correct IRQ
`if irq == 7 then outport_byte(0x21, inport_byte(0x21) | 0x21)`	mask the correct IRQ
`Setvect(irq + 8,oldvect)`	restore the old interrupt vector
`enable()`	reenable interrupts once the change is completed