User's Guide

CS100 Controller and ET Series II Servo-stabilized Interferometer System

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Electromagnetic Compatibility

CE

The CS100 Fabry Perot Etalon Control System conforms with the protection requirements of Council Directive 89/336/EEC, relating to Electromagnetic Compatibility, (emissions) by the application of the following EMC Standard:

BS EN 50081-1 1992 Emissions Standard, Residential, commercial and light industrial (Class B level).

The CS100 relies for its operation on the detection of very small signals from its capacitance bridge. As such, exposure to interference fields as defined in BS EN 50082-1 1992 Immunity Standard, Residential, commercial and light industrial *may* cause the CS100 to revert from OPERATE to BALANCE mode. Correct operation can be restored after removal of the field by switching to BALANCE and back to OPERATE and, if required, resetting the X, Y and Z interface registers. Immunity can be improved by use of extra shielding around the etalon cables. Please consult IC Optical Systems for advice on use of the CS100 in high interference field environments.

Contents

Chapter 1 Introduction

This User's Guide describes the operation and use of IC Optical Systems ET-Series II ambient temperature etalons with the CS100 control system.

What is the ET etalon System?

The servo-stabilized Fabry-Perot interferometer system comprises ET-Series II etalons and the CS100 control unit, which stabilizes the etalon spacing and parallelism.

How does it work?

The CS100 is a three-channel controller, which uses capacitance micrometers and PZT actuators, incorporated into the etalon, to monitor and correct errors in mirror parallelism and spacing. Two channels control the parallelism and the third maintains spacing by referencing the cavity length-sensing capacitance micrometer to a fixed reference capacitor. Because this is a closed-loop system, non-linearity and hysteresis in the PZT drive are eliminated completely, as of course are drifts in mirror parallelism and spacing.

The CS100 can be operated manually from front panel controls, or under computer control using either the IEEE-488, RS232C or analogue interfaces.

How stable is it?

The CS100 will control the etalon spacing and parallelism to better than 0.01% of a free spectral range (FSR). Stability of the transmitted wavelength will depend on the ambient environment, and can be as good as 1 part in 10^{10} if the etalon is mounted in a stable environment such as a IC Optical Systems sealed cell which has been temperature stabilized.

Compatibility with earlier models

The CS100 and ET etalons described in this User's Guide are the latest models in a system, which was first introduced in 1979. This guide describes CS100 systems with serial numbers 8035 and greater, ET-Series II etalons with serial numbers of 879 or greater.

All CS100s and etalons are inter-compatible using adapter cables available from IC Optical Systems.

Operating Principles

The arrangement of capacitance sensors and piezoelectric (PZT) actuators to be found in ET and EC series etalons is shown schematically in Figure 1.1. Three piezo-electric actuators (a, b, c) are used to tune the cavity while the capacitance sensors Cx_1, Cy_1 etc., fabricated onto the mirror surface, are used to sense changes in parallelism and cavity length.

Parallelism information is obtained by comparing Cx_1 with Cx_2 (X-channel) and Cy_1 with Cy_2 (Y-channel). Cavity length control is achieved by referencing Cz to a stable fixed reference capacitor (Z-channel).

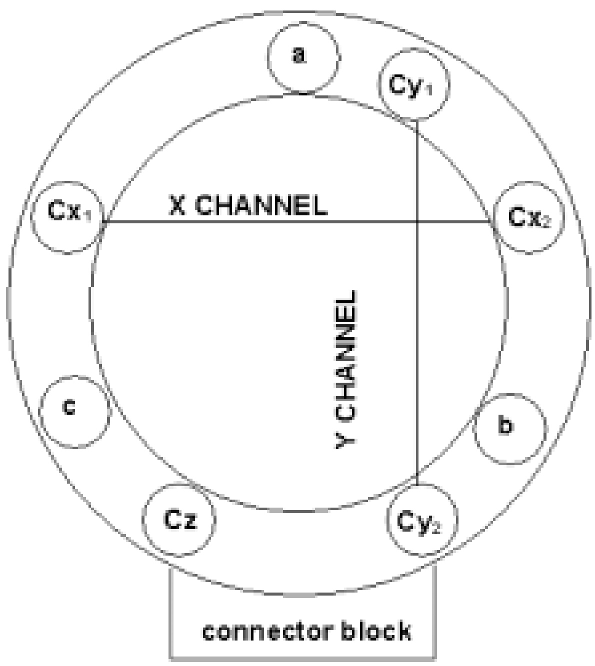


Figure 1.1 Etalon Schematic

The X and Y capacitance bridges can be un-balanced by means of the front panel controls or the interface to compensate for differences in micrometer capacitor values when the plates are parallel. Varying the balance will cause the plates to tilt so they can be accurately aligned. Similarly the Z channel can be un-balanced causing the plate spacing to vary enabling the etalon to be tuned to a particular wavelength.

Chapter 2 The CS100 Controller

This section contains a general description and specification of the CS100 controller, including the front and rear panel controls and user interfaces.

General Description

The CS100 control unit contains the three-axis capacitance bridge stabilization system, which enables the parallelism and cavity spacing of the etalon to be servo-stabilized. It also houses the PZT power supplies to drive the etalon, along with front panel manual set-up and scan controls and rear panel interfaces for computer control.

Manual Controls

Figure 2.1 shows a schematic diagram of the CS100 front panel and Figure 2.2 the CS100 rear panel.

On the front panel are the controls for manual setting of the static and dynamic response of the etalon. The X and Y PARALLELISM and QUADRATURE BALANCE controls allow the capacitance bridges to be balanced and the etalon mirrors aligned parallel: the meters are switchable to display either the real or imaginary part of the imbalance signal. Other manual controls include a selectable RESPONSE TIME, and BALANCE/OPERATE to switch from set-up mode (BALANCE) to closed-loop control (OPERATE).

Interfaces

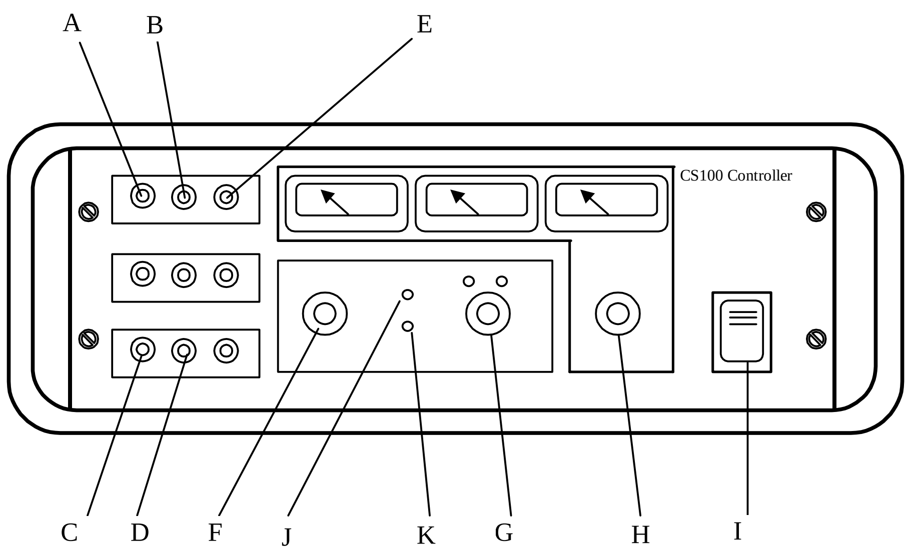
On the rear panel are mounted the user interface, IEEE-488 or RS232C, by which the system can be computer controlled. All the functions controllable manually from the front panel, with the exception of the COARSE OFFSET and QUADRATURE BALANCE, can be controlled via the interface. A full description of the interface is contained in Chapter 5.

Z Modulation

A two-pin socket is provided on the CS100 rear panel to enable analogue control of the etalon spacing. A plus or minus 10V differential input will produce plus or minus 1000nm of plate movement for standard ET Series II etalons. This input is intended for modulation of the etalon plate spacing for applications that require differentiation of the transmitted line profile etc. It is not intended as the prime means of scanning the etalon, as the linearity is poor compared to that available from the RS232C or IEEE-488 interface. It can, of course, be used for scanning if the non-linearity can be tolerated.

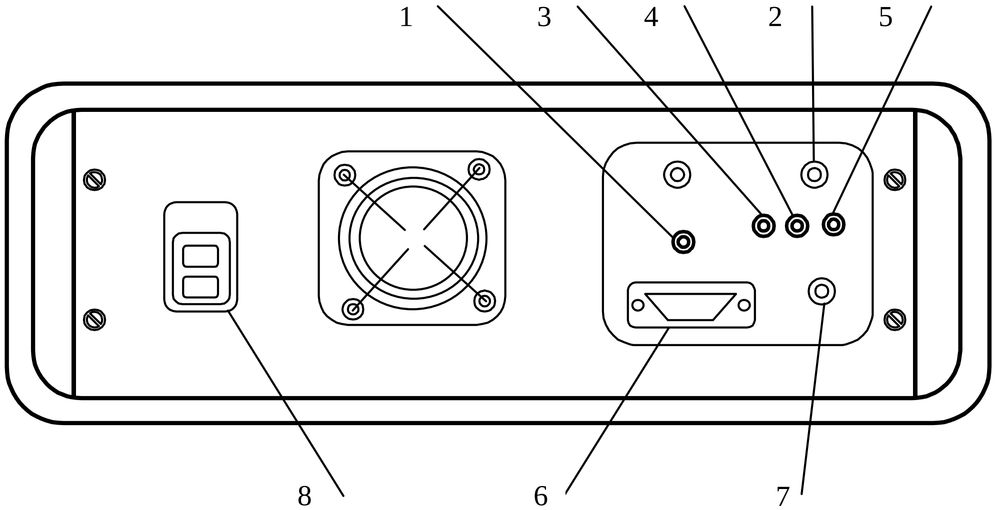
Protection

System will enter BALANCE mode and indicate OUT OF RANGE within 0.5s when driven out of range of the piezo-electric transducers or when an oscillatory RESPONSE TIME is set.



	Control/Indicator	Comments
A	PARALLELISM	Fine 10 turn pot. X & Y
B	PARALLELISM	Coarse switch X & Y
C	SPACING	Fine Z
D	SPACING	Coarse Z
E	QUADRATURE BALANCE	X, Y & Z
F	RESPONSE TIME	
G	BALANCE / OPERATE	Indicators show status
H	METER DISPLAY	Selects Quad. error / offset
I	POWER	With indicator
J	OUT OF RANGE	Indicates X, Y or Z bridges out of range
K	DISABLED	Front panel controls disabled via interface

Figure 2.1 CS100 Front Panel



CONNECTORS			
#	Type	Purpose	Comments
1	LEMO PSA 0S 302 CLLC 37	Z-MODULATION	
2	LEMO PSA 1S 305 CLLC 37	BRIDGE DRIVES	PINS 1,2,3,4
3	LEMO PSA 00 250 CTLC 27	X-ERROR SIGNAL	
4	LEMO PSA 00 250 CTLC 27	Y-ERROR SIGNAL	
5	LEMO PSA 00 250 CTLC 27	Z-ERROR SIGNAL	
6	AMPH.57FE-40240-20S D1(IEEE) OR AMPH. 17D-B-FR-A-25-S(RS232)	INTERFACE	CONNECTOR TYPE OPTIONAL
7	LEMO PSA 2S 306 CLLC 42	PIEZO DRIVES	
8	BULGIN PF0011/63/30	LINE	I.E.C. MAINS PLUG

Figure 2.2 CS100 Rear Panel

Specification

The following specification relates to a CS100 with serial number 8035 or greater, controlling any standard IC Optical Systems ET Series etalon with 3m cables.

Front Panel X, Y & Z Set-up Control Range

The front panel PARALLELISM and BALANCE fine and coarse controls have the following ranges:

FINE	COARSE
±530nm	±5000nm

Response Times and Slew Rate

RESPONSE TIME switch selects the following responses. The 'STANDARD' response time (blue scale on the CS100) is for standard ET Series etalons. The 'LONG RANGE' response time (black scales) is appropriate to etalons fitted with long-range piezo-electric actuators. See the section on 'Response Time' in Chapter 5 for the definitions of standard and long-range piezos. Note: A response time of 0.1msec, available for etalons with long-range piezos, may cause system instability. The system may enter BALANCE mode.

STANDARD	LONG RANGE
0.2msec	0.1msec
0.5msec	0.2msec
1.0msec	0.5msec
2.0msec	1.0msec

Table 2.1 Response Time for Standard and Long Range PZTs

STANDARD	LONG RANGE
>1600nm $msec^{-1}$	>1600nm $msec^{-1}$

Table 2.2 Slew Rate for Standard and Long Range PZTs

Interfaces

Interface range and resolution are shown in Table 2.3. A full description of the use of interfaces are given in Chapter %.

Parameter	Value
Range	±1000nm
Resolution (12 bits)	0.49nm
Non-linearity of scan	±0.05%
Accuracy	±0.5 lsb (when calibrated)

Table 2.3 X, Y and Z Interface Control Range and Resolution.

Z - Modulation

Parameter	Value
Range	±1000nm for ±10V differential input
Non-linearity	±1%
Frequency Response	dc to limit set by RESPONSE TIME (see Table 3.5

Table 2.4 Z Modulation Specifications

Response Time (ms)	Frequency Response, Hz 3dB point
0.2	800
0.5	320
1.0	160
2.0	80

Table 2.5 Response Time vs Frequency Response.

Drift and Noise

All displacements refer to relative etalon plate movement.

Parameter	Value
Noise Equivalent Displacement	<10 pm $Hz^{-1/2}$
Temperature Coefficient	0±50 pm K^{-1}

Table 2.6 Electronic Noise and Temperature Coefficient of the Cavity

Installation

A schematic diagram of the CS100 is shown in Figure 2.3.

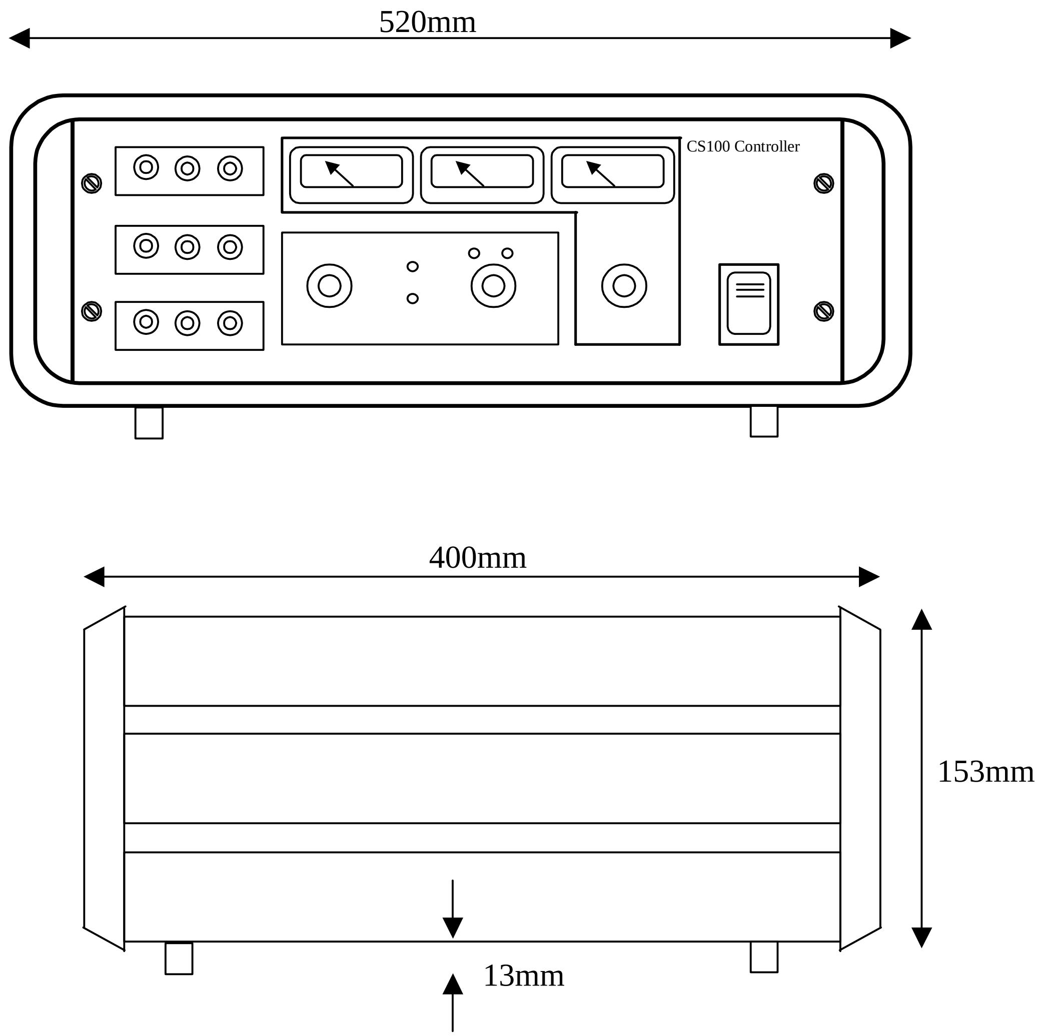


Figure 2.3 CS100 Installation Drawing.

Chapter 3 ET Series II Etalons

This chapter describes the IC Optical Systems ET-Series II Fabry-Perot etalons and accessories.

General Description

The standard ET range of fused silica (FS) etalons have clear apertures between 28mm and 140mm with matched surface qualities of $\lambda/50$, $\lambda/100$ and $\lambda/200$ (λ=633nm) before coating.

ET etalons are available in water-free fused silica (WF) for use in the near infrared. The ET28 and ET50 are also available in zinc selenide (ZS) for use out to 15μm wavelength and in crystalline quartz (CQ) or magnesium fluoride (MF) for the ultraviolet.

Imaging

The rear surfaces of the etalon mirrors are wedged by nominally 15 minutes of arc. Optionally, etalons are available with front and rear mirror surfaces polished optically parallel to each other. This will eliminate 'ghost' reflections, which are displaced from the main image when the etalon is used for two-dimensional spectral imaging.

Glass Reference Capacitor

An optional glass reference capacitor is available. Fabricated in the style of the gap-sensing capacitance micrometers, this will reduce the impact of changes in ambient temperature, pressure and humidity on the capacitance bridge controlling the cavity spacing. The parallelism channels are self-compensating. This option is available on the ET50 and larger etalons.

Sealed Cell

For applications where the highest possible stability is required, the ET-Series II etalon is available mounted in a sealed cell with high efficiency anti-reflection coated windows. This eliminates the impact of changes in environmental pressure and humidity on both the capacitance micrometers and on the optical cavity length. With a sealed cell the cavity can be stabilized to ~1 part in 5.10^8, corresponding to a transmitted wavelength stability ~10MHz.

Specification

Parameter	Value
Clear Aperture (mm)	28, 50, 70, 85, 100, 116, 150
Surface Quality	λ/50-λ/200 defined at 633nm
Wedge Angle	Zero ±1 fringe or 10-15 arcmin (nominal)
Mirror Spacing	Specified by user in range 3µm to 30mm
Coatings	User Specified
Cavity Tuning Range	3µm nominal (>6µm optional)
Operational Temperature Range	10-40C
Storage Temperature Range	-20C to +70C (non condensing)
Response Time when used with CS100 Controller	0.2ms – 2.0ms

Table 3.1 ET Series II Etalon Specifications

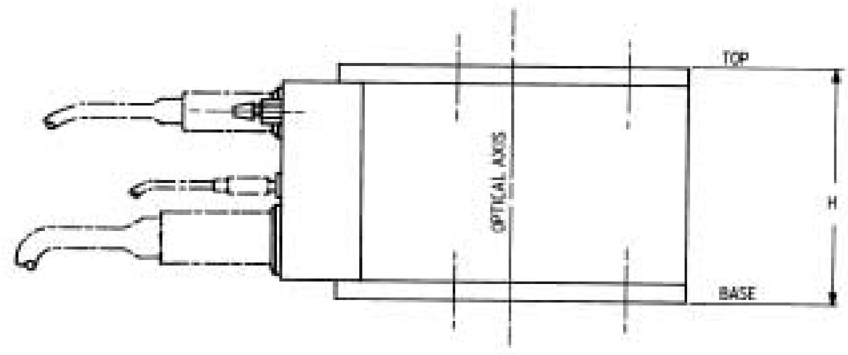
Installation

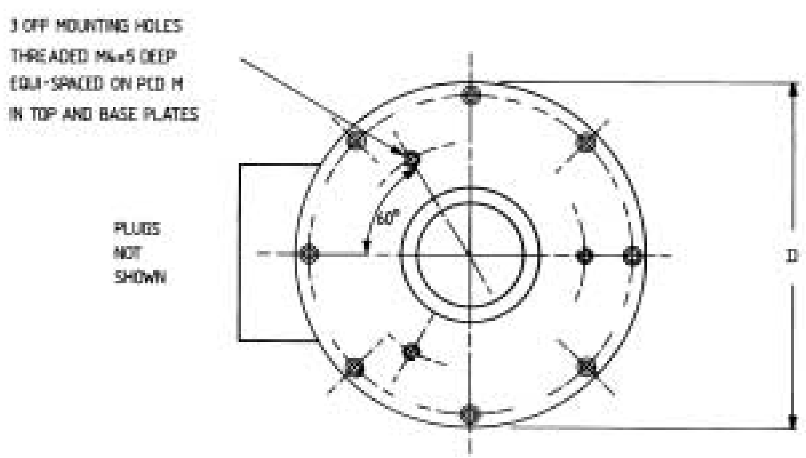
Mechanical

Figure 3.1 shows a drawing for the ET-Series II etalon. Tapped holes are provided in the cell end plates for mounting.

Use of Gas Connector

A connector is provided with standard ET Series II etalons to allow the user to flush the etalon with a dry gas such as oxygen free nitrogen to minimize the effects of changes of ambient humidity on the capacitance micrometers.



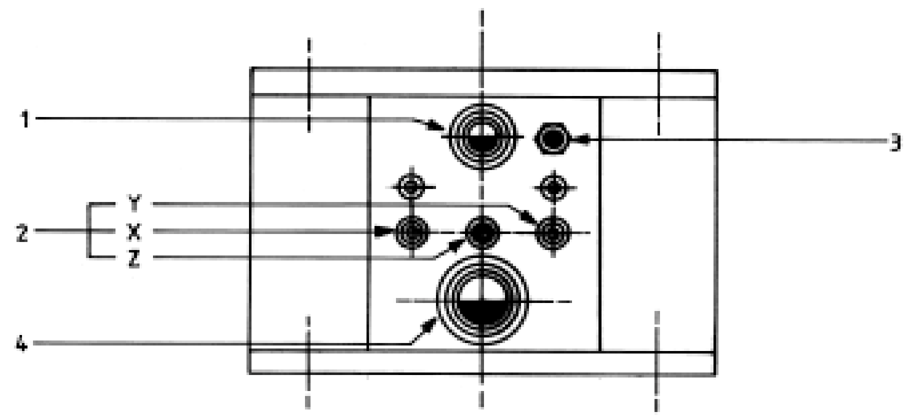


Model	Clear Aperture	Diameter (D)	Height (H)	Mounting PCD (M)
ET28	28	100	60	66
ET50	50	125	67	86
ET70	70	153	75	120
ET100	100	170	100	142
ET116	116	194	112	151

All dimensions in mm for guidance only

Figure 3.1 ET Series II Mechanical Interfaces (standard cells only)

Electrical



	CONNECTORS		
Station	Type	Purpose	Comments
1	LEMO ERA 1S 305 CLL	BRIDGE DRIVES	PINS1,2,3,4
2	LEMO ERA 00 250 CTL	Y ERROR SIGNAL	
2	LEMO ERA 00 250 CTL	X-ERROR SIGNAL	
2	LEMO ERA 00 250 CTL	Z-ERROR SIGNAL	
3	KUHNKE(50-704)	GAS CONNECTOR	
4	LEMO EGJ 2B 306 CLA	PIEZO DRIVES	

Figure 3.2 Etalon Plug Block and Electrical Connections

Care of Etalon

Store the etalon in the instrument case provided when not in use. Always keep in a clean, dry environment.

Avoiding Condensation

In preparing for use, allow time for the etalon to reach ambient temperature. This is particularly important to prevent condensation forming on the mirrors, and to minimize distortions of the mirror surfaces due to temperature gradients in the glass. Typically, an ET28 or ET50 will require 1 hour to stabilize, whereas an ET140 could take up to 6 hours.

To prevent condensation forming when taking an etalon from a cold to a warm environment, it is advisable to seal it in a plastic bag until it has reached ambient temperature.

Should condensation form on the front or rear surfaces of the mirrors, allow it to disperse naturally as the system reaches ambient temperature. Under no circumstances should condensation be wiped away, as this may damage the optical coatings.

Cleaning

Dust can be removed from the outer surfaces of the etalon with a filtered air blower. Under no circumstances should the outer surfaces be wiped clean. Stubborn dust particles may be removed with the corner of a folded lens tissue, but do not wipe.

Solvents and other liquid cleaners must not be used under any circumstances.

The antireflection coatings on the outer surfaces of the sealed cell windows are durable, and can be cleaned with a soft brush or a lens tissue slightly moistened in isopropyl alcohol.

Chapter 4 Getting Started

Connect the etalon to the CS100 rear panel connectors using the cable loom provided. Take care when connecting the X, Y and Z ERROR SIGNALS: the connectors used for the three channels are identical so it is possible to cross over these connections. Faulty connection of the error signals will do no damage but the system will not work correctly.

The capacitance micrometers are very sensitive and can be upset by electromagnetic interference. It is good practice to route the etalon connection cables away from interference sources such as computer monitors and the RS232C or IEEE-488 interface cable. Electromagnetic interference will cause the etalon plates to 'wobble' resulting in movement of the fringes and modulation of the transmitted light intensity.

Balancing the Capacitance Bridges

As supplied the plates of an ET Series etalon will not be exactly parallel, typically there will be a manufacturing error of one or two fringes across the mirror diameter.

The etalon will be supplied with a table of settings for the CS100 front panel PARALLELISM, SPACING and QUADRATURE BALANCE controls. When these settings are used the etalon should be aligned parallel and ready for use. However ageing effects will cause these settings to change with time, and it will be instructive for the user to follow the full alignment procedure.

Initial optical alignment is best done either by eye for etalons, which operate in the visible, or using a remote viewer for etalons coated for the infrared.

There are two procedures to be followed to align the etalon if the settings are not known. Once these have been followed a given CS100/etalon system can be switched on and used with no further set-up.

The first procedure balances the capacitance bridges with the etalon in its un-parallel, as-supplied state.

- Set up the system as shown in the Figure 5.1.
- Referring to Figure 2.1, set the MODE control to BALANCE, the METER DISPLAY switch to OFFSET and the RESPONSE TIME to 0.5ms on the black scale. Turn on the power. The yellow

BALANCE indicator will illuminate. The red POWER indicator, mounted in the POWER switch, will also illuminate within about 1 second. The three meters may go off scale.

- Turn the X COARSE switch to bring the X meter as close to zero as possible. Turning the switch clockwise will move the meter needle from left to right. Zero the meter using the X FINE 10-turn control.
- Repeat using the Y and Z controls, observing the Y and Z meters respectively.
- Set the METER DISPLAY switch to QUADRATURE ERROR.
- Null the X meter using the X QUADRATURE BALANCE 10-turn control.
- Null the Y and Z meters using the Y and Z QUADRATURE BALANCE controls respectively.
- Set the METER DISPLAY switch back to OFFSET and re-zero them if necessary using the respective COARSE and FINE controls.
- Turn the MODE switch from BALANCE to OPERATE. The yellow BALANCE indicator should go out and the green OPERATE indicator should come on after a delay of about 2 seconds.
- Turn the METER DISPLAY switch to QUADRATURE ERROR and null any offset using the relevant QUADRATURE BALANCE controls.
- Turn the METER DISPLAY switch back to OFFSET. The meters should all read within about 1V of zero.

The CS100 is now controlling the etalon in its as-supplied state. The next procedure aligns the plates to be parallel.

Aligning the Etalon

Using the optical set-up of Figure 5.1 with a suitable spectral lamp or laser plus beam expander, straight-line fringes should be visible on the screen. If the etalon plates are almost parallel, the fringe spacing may be too much for a fringe to be visible. In this case turn the Z FINE control until a fringe appears. When the etalon plates are parallel, the fringe will be expanded to fill the whole aperture.

- Set the METER DISPLAY switch to QUADRATURE ERROR.

- Turn the Z FINE control backwards and forwards. The fringe should move backwards and forwards in a direction perpendicular to its length.

- Turn the X COARSE and FINE controls until the movement observed above is predominately along the Y axis. (For a definition of axis orientations see Fig. 1.1). While doing this, keep the meters within a couple of volts of zero using the relevant QUADRATURE BALANCE controls. If any meter exceeds about 5V, the OUT OF RANGE indicator may illuminate and the system revert to BALANCE mode. If this happens, turn the last turned control back a few positions and set back to OPERATE mode by turning the MODE switch to BALANCE and then back to OPERATE.

- Turn the Y COARSE and FINE controls to expand the fringe until it fills as much of the aperture as possible. Again keep the meters within a couple of volts of zero.

- Keep adjusting the X and Y FINE controls until turning the Z FINE control causes the field to lighten and darken uniformly.

- Null the meters exactly using the QUADRATURE BALANCE controls and verify that the plates are still aligned.

- Turn the METER DISPLAY back to OFFSET. The meters will not now read zero but will give an indication of how much correction is being applied in the three axes to achieve parallelism at the spacing required to transmit the fringe used for alignment. Usually the X and Y meters will read 0 plus or minus 5V and the Z meter 0 plus or minus 2V.

- Record the PARALLELISM and SPACING control settings and QUADRATURE BALANCE settings for future reference.

The etalon plates are now aligned parallel and will remain so while the CS100 is switched on.

To switch off:

- Turn the MODE switch to BALANCE.

- POWER to off.

When the system is to be used again with a given etalon, ensure that the PARALLELISM, SPACING and QUADRATURE BALANCE controls are as recorded for that etalon, turn on power and set MODE from BALANCE to OPERATE. The OPERATE indicator will illuminate and the etalon will be parallel as before.

It should be noted, of course, that this simple procedure will only work for etalons that are coated for use in the visible part of the spectrum. It may not be possible to see any fringes at all with some ultra-violet or infrared etalons. For these etalons, the users optical system and detector must be employed and the parallelism adjusted for minimum transmission peak width.

Response Time

If a step in plate spacing is requested either by turning the Z COARSE front panel control or via the interface, the etalon plates cannot respond instantaneously. The RESPONSE TIME switch gives some control over the time taken for the plate position to stabilise. There are two scales for different types of etalon. Etalons designed for use in the visible and ultra-violet region of the spectrum will have response times given by the black scale. Infrared etalons have higher sensitivity piezo-electric actuators, which produce a more rapid response from the servo-control loop. Their response time is given by the blue scale.

The times quoted are approximate and correspond to the time taken to reach 60% of the demanded step distance. The settling time should be taken as three times this value.

A choice of response times is provided to give some control of the system noise. If a rapid response time is selected the system bandwidth is increased and thus the total system noise will be increased. Electronic noise will cause the etalon plates to make small amplitude random movements about their mean position, which effectively broaden the instrumental profile or modulate the transmitted light. Whether or not this is a problem depends on the specific application. The following table gives the approximate total RMS noise, in pico-metres, on the etalon plate position as a function of set response time.

Response Time / ms	RMS Noise / pm
0.2	230
0.5	180
1.0	130
2.0	90

Table 4.1 Response Time and RMS noise

It will be observed that it is possible to set a response time of 0.1ms using an infrared etalon (with long range PZTs). This response time

is not recommended however as the servo-control loop may become unstable, resulting in an audible oscillation from the etalon. Such oscillation will result in the OUT OF RANGE indicator lighting and the system reverting to BALANCE mode.
To return to OPERATE mode:

- Select a longer response time.
- Turn the MODE switch from OPERATE to BALANCE and back to OPERATE.

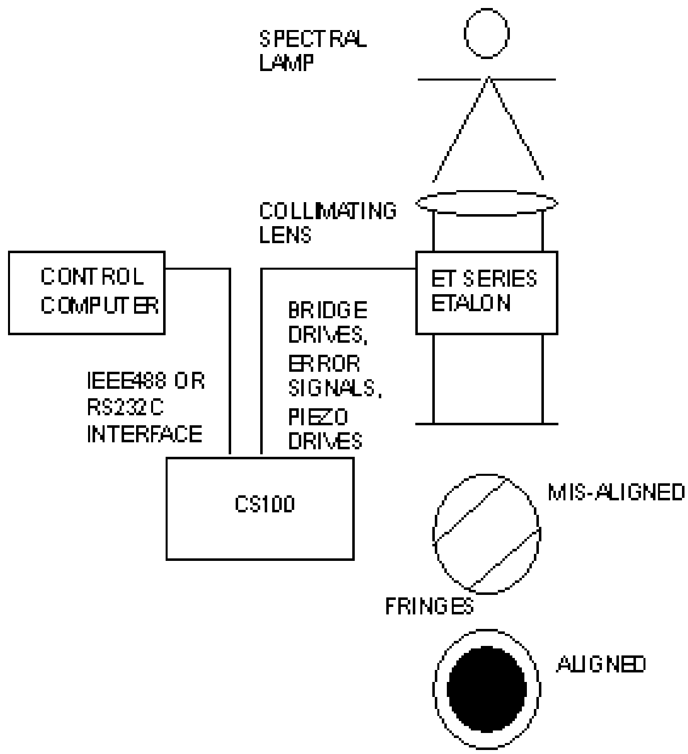


Figure 4.1Aligning the Etalon

Chapter 5 Interface Operation

This section describes the operation and use of the CS100 RS232C and IEEE-488 interfaces. Only one of the above interfaces, specified at the time of purchase, is incorporated in the CS100.

The protocol for CS100 operation is similar for both interfaces.

Controllable Functions

Write Operations

Table 6.1 shows the functions that can be controlled by writing to the interface, their argument ranges and equivalent function ranges. The commands that have to be issued to implement these functions are detailed in the section entitled 'Controlling the CS100'. The function ranges for the X and Y PARALLELISM and Z SPACING is given in nanometers (nm) of etalon plate movement, the wavelength scan range corresponding to the Z SPACING range will depend on the absolute etalon plate spacing.

Function	No. of Bits	Argument Range	Function Range
X Parallelism	12	-2048 to +2047	±1000nm
Y Parallelism	12	-2048 to +2047	±1000nm
Z Spacing	12	-2048 to +2047	±1000nm
Response time	4	-	0.2ms, 0.5ms, 1.0ms, 2.0ms
Mode	1	0.1	BALANCE, OPERATE
Enable	1	0.1	ENABLE, DISABLE

Table 5.1Available Write Operations

Read Operations

The information that can be read back via the interface is shown in table 5.2.

Function	No. of Bits	Numeric Range	Function Range
Z Spacing	12	0 to 4095	±1000nm
Status	2	-	Mode, out of range

Table 5.2 Available Read Functions

The Z SPACING word read back is the same as the Z SPACING word previously written to the interface, offset by +2048 and can be used as an optional check of correct write/read operation during scans. If Z SPACING is set as -2048 the read-back will be 0. A written Z SPACING of +2047 will give a read-back of +4095.

The STATUS word contains two bits, one indicating the current operation mode of the CS100, the other indicating an OUT OF RANGE state caused by setting too fast a response time or requesting too large a spacing change.

Communicating with the Interface

Commands and data are transferred between the interface and host computer as ASCII coded characters on the IEEE-488/RS232C bus. The commands as described in this section are quite versatile but this versatility leads to a rather un-friendly protocol. There are examples given in section entitled 'Software Examples' which should help to clarify their use.

Interface Organization

The interface is arranged as 12 four-bit ports labelled I to T, see Fig.6.1. Ports Q,R,S and T are set up for read operations (data transfer from the port to the IEEE-488/RS232C bus) and ports I,J,K,L,N,O and P for write operations. Port M is not used. For discussion purposes the individual bits of the ports are labelled "a" to "d". "a" represents the least significant bit and "d" the most, thus Id denotes the most significant bit of port I. Data written to a port will stay there until overwritten. [It would perhaps be more conventional to label bits with numbers, i.e. 0 to 3, but this could lead to confusion with valid command strings such as I2]

Ports J,K and L are used to create a 12 bit word which is latched into the X, Y or Z buffers depending on the contents of the I port and bit Pa. Bit Pa must be set to 1 to enable operation of the I bits. Bit Ia opens the X buffer, Ib the Y and Ic the Z buffer. Bit Id is ignored. The ports are opened independently by the individual bits, so setting bits Ia,b and c to one will transfer the word on ports J,K and L to X, Y and Z simultaneously. This is useful for resetting the buffers to zero.

Ports N and O are used to control various CS100 operations as described in the section entitled 'Controlling the CS100' (see below).

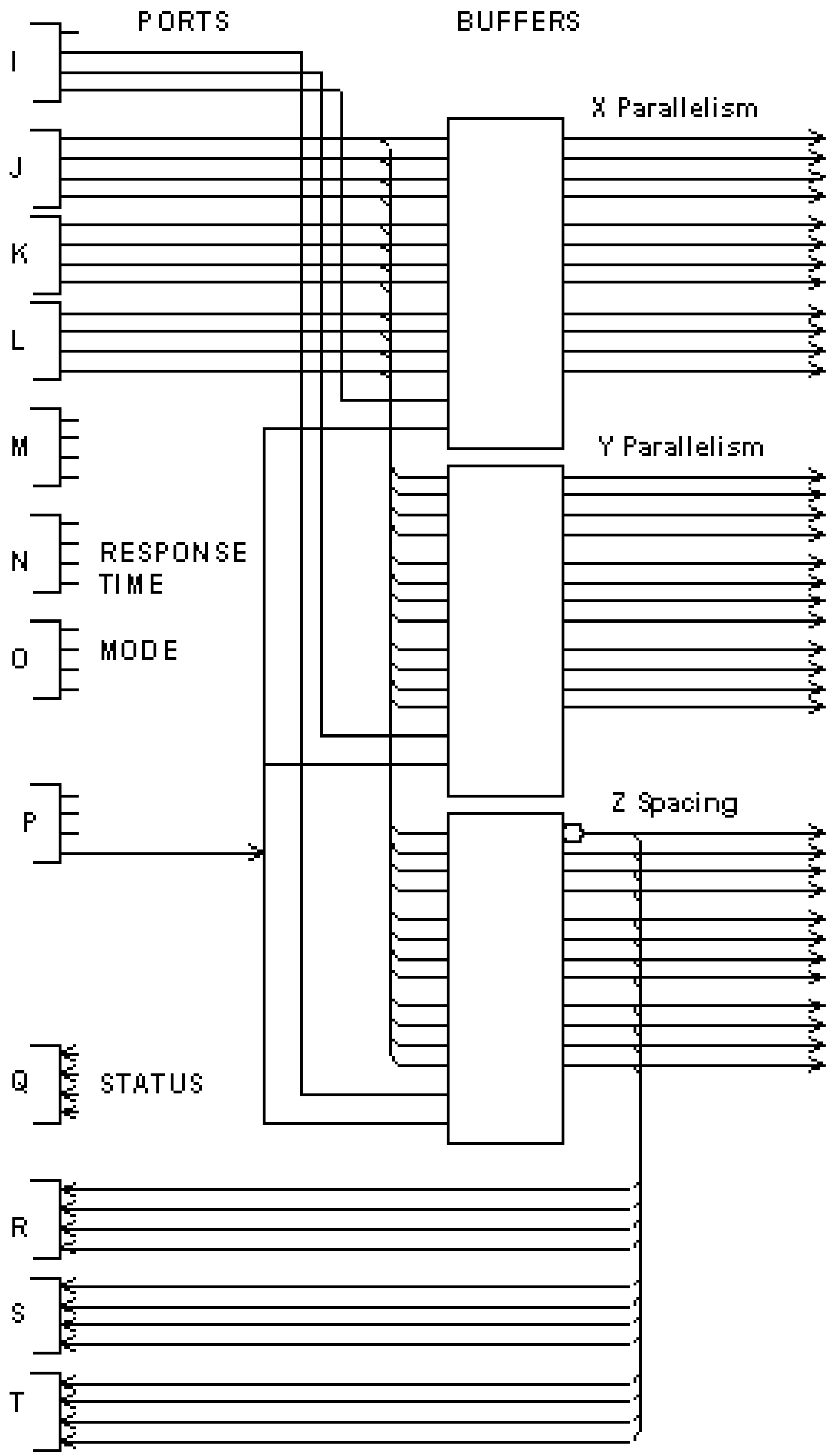


Figure 5.1 Interface Organisation

Writing to a Port

Commands and data are sent to the interface as character string on the IEEE-488/RS232C bus. Some characters have different functions depending on interface type. Table 4.3 shows the characters used.

Character	ASCII Code (Hex)	Function
0 to 9	30 to 39	Data
A to F	41 to 46	Write Port designation
I to P	49 to 50	Read Port designation
Q to T	51 to 54	Define read ports (RS232)
!	21	Define read ports (IEEE-488)
*	2A	Read from port (RS232 only)
?	3F	Logical AND to port
+	2B	Logical OR to port
/	2F	Carriage return (end of data designation)
<CR>	0D	Omit Line Feed at end of read data (IEEE-488 only)

Table 5.3 Command and Data Characters

To write to a port, the port designator and data are transmitted followed by a Carriage Return (**Note:** the IEEE-488 interface recognises EOI asserted with the last character sent as a data terminator. The Carriage Return is not then required). Thus:

I1<CR> Sets port I to 1

N0<CR> Sets port N to 0

If a contiguous sequence of ports is to be set, only the first port designator need be transmitted. Thus:

J12F<CR> Sets port J to 1, K to 2, L to F.

Commands and data can be combined into strings up to 31 characters long, for example of a longer string:

I7000I0<CR> Sets port I to 7; J,K and L to 0 and then I to 0.

To set or clear individual bits of a port, the OR and AND functions can be used. For example:

I/1<CR> Sets bit Ia to 1 and leaves the other bits unchanged.

O/3<CR> Sets bits Oa and Ob to 1 and leaves the other bits unchanged.

+E<CR> Clears bit Ia to 0 leaving the others unchanged

WARNING! Do not write to the read ports Q to T. This will set them to be write ports with unpredictable results.

Reading from a Port

Ports Q,R,S and T are used to read back data from the CS100. These are set by default to be read ports but it is good practice to initialise them in the software. This is done using the "!" character for an RS232C interface or "*" character for an IEEE-488 interface.

!QT<CR> Define read ports Q to T (RS232C)

*QT<CR> Define read ports Q to T (IEEE-488)

This initialisation sequence need only be performed once on CS100 power up, or after pressing the CS100 rear panel Interface Reset switch.

To read back data from the RS232C interface, the "?" character is sent. Thus:

?<CR> Causes four characters followed by a <CR> and LF to be transmitted from the CS100 to the users computer.

To read back this data from the IEEE-488 interface, an interface read operation is performed. If the LF character is not required at the end of the data, a "#" character may be transmitted as part of the initialisation sequence. This is only valid for the IEEE-488 interface. (**Note:** Although the IEEE-488 interface recognises EOI asserted with the last character sent to it as a data terminator, it does NOT assert EOI when it sends data back to the computer. The computer interface must therefore be set up to recognise Carriage Return or Carriage Return plus Line Feed as a data terminator.)

Controlling the CS100

Port Functions

The function of the various port bits is shown in Table 5.4 below.

Bit	Read/Write	Function
Id	Write	Not used
Ic		Open Z buffer
Ib		Open Y buffer
Ia		Open X buffer
Jd	Write	MSB
Jc		
Jb		
Ja		
Kd	Write	
Kc		Write Data Word
Kb		
Ka		
Ld	Write	
Lc		
Lb		
La		LSB
Md	Write	Not used
Mc		
Mb		
Ma		
Nd	Write	Select 2.0ms Response Time
Nc		Select 1.0ms Response Time
Nb		Select 0.5ms Response Time
Na		Select 0.2ms Response Time
Od	Write	Not used
Oc		
Ob		Set LOCAL operation
Oa		Set OPERATE mode
Pd	Write	Not used
Pc		
Pb		
Pa		Enable X, Y and Z buffer
Qd	Read	Not Used
Qc		
Qb		OUT OF RANGE status bit
Qa		OPERATE status bit
Rd	Read	MSB
Rb		
Rc		
Ra		
Sd	Read	
Sc		Read Data Word
Sb		
Sa		
Td	Read	
Tc		
Tb		
Ta		LSB

Table 5.4 Port Bit Functions

Data Coding

Data for X and Y Parallelism and Z Spacing is offset binary coded as shown in Table 5.5

Bit Pattern	Hexadecimal	Decimal
0111 1111 1111	7FF	+2047
0111 1111 1110	7FE	+2046
* * *	* * *	*
* * *	* * *	*
0000 0000 0001	001	+1
0000 0000 0000	000	0
1111 1111 1111	FFF	-1
* * *	* * *	*
* * *	* * *	*
1000 0000 0001	801	-2047
1000 0000 0000	800	-2048

Table 5.5 Offset Binary Coding

Setting and Scanning Z

To set Z SPACING, the Z buffer must be opened, the required value written into the data register formed by ports J,K and L and the transfer to the buffer enabled by setting bit Pa. Clearing Pa at the end prevents further changes in data coming through until required.

I47FFP1P0<CR>   Set Z SPACING to +2047

To scan an etalon a sequence of numbers must be written to Z SPACING. The users' program would normally provide a pause between steps for data collection etc. Thus to scan from 0 to 10 in steps of 2 the following data would be sent to the interface:

I4<CR>   Open Z register

J000P1P0<CR>

J002P1P0<CR>

J004P1P0<CR>

J006P1P0<CR>

J008P1P0<CR>

J00AP1P0<CR>

I0<CR>   Close Z register

If required, data may be read back after each step by including a "?" after each P0 above (RS232C), or performing a read operation (IEEE-488).
Setting Parallelism

The etalon parallelism may be set in the same way as setting Z. Thus:

I2800P1P0<CR> Set Y PARALLELISM to -2048

I1FFFP1P0<CR> Set X PARALLELISM to -1

I0<CR> Close all latches

Setting Response Time

The response time may be chosen by setting individual bits of port N. This function is enabled by clearing bit Ob to zero. For example:

O+D<CR> Disable local control, enable external control.

N1<CR> Set 0.2ms response time

While bit Ob is zero, the 0.2ms response time selected will be active. Setting bit Ob to 1 again will enable the front panel controls and the response time will be as set by the RESPONSE TIME switch.

O/2<CR> Enable local control, disable external control

Selecting response times via the interface with the front panel controls disabled (front panel DISABLED indicator illuminated) gives the possibility of choosing longer response times than are available from the front panel. If more than one bit is set, two or more response times can be selected and the result will be the sum of the individual responses. Thus:

O+DNC<CR>Selects 2.0ms + 1.0ms, i.e. 3.0ms

Selecting zero response time will result in an OUT OF RANGE indication and the CS100 will enter BALANCE mode.

Changing Mode

The CS100 operating mode can be selected by changing bit Oa. This duplicates the action of the front panel MODE switch, but is only active when enabled by clearing bit Ob (c.f. setting response time).

O0<CR> Set OPERATE mode

O1<CR> Set BALANCE mode

O2<CR> Mode selected by front panel MODE switch

O3<CR> Mode selected by front panel MODE switch

Reading Status

When a read operation is performed on the IEEE-488 interface or read data is requested by sending a "?" character on the RS232C interface, four characters are received followed by CR LF (carriage return, line feed). The first character is the bit pattern on port Q which carries status information. Bits Qa and Qb are the relevant ones, bits Qc and Qd are undefined.

Bit	Level	Indication
Qa	0	System in BALANCE mode
Qa	1	System in OPERATE mode
Qb	0	OUT OF RANGE indication
Qb	1	Not out of range

Table 5.6 Status Indication

If an OUT OF RANGE state is indicated, the system will have automatically entered BALANCE mode.

Reading Z Spacing

The second, third and fourth characters received during a read operation represent the bit pattern on ports R, S and T. This will be the same as the last word written to the Z Buffer but with the most significant bit (Rd) inverted. Thus if Z had been set to 7FF, the readback would be FFF.

Software Examples

The program examples given here are written in MicroSoft QuickBasic but should be readily adaptable to other languages. It is assumed that the user has a routine OutputString(a$) that can transmit a character string a$ to the interface in use and a function InputString$ that returns a string read from the interface. It is further assumed that if an RS232 interface is used, OutputString(a$) appends a carriage return character to a$ before transmitting it. This is not required for an IEEE-488 interface.

Initialisation

This program fragment will set up the read ports, zero the X, Y and Z buffers and ensure that front panel controls are enabled.

```
RS232

CALL OutputString("!QT")      'Set read ports.
CALL OutputString("P0")       'Ensure buffers disabled
CALL OutputString("I7000P1P0")'Open X,Y and Z buffers,
                              'set ports J,K,L to
                        'zero, latch the data.
CALL OutputString("I0")             'Close the buffers.

CALL OutputString("O3")             'Balance mode, but front
                              'panel has control.
IEEE-488

CALL OutputString("#*QT")           'Set read ports and
                              'inhibit LF transmission
CALL OutputString("P0")             'Ensure buffers disabled
CALL OutputString("I7000P1P0")'Open X,Y and Z buffers,
                              'set ports J,K,L to
                        'zero, latch the data.
CALL OutputString("I0")             'Close the buffers.

CALL OutputString("O3")             'Balance mode, but front
                              'panel has control.
```

Scanning Z

Sending strings directly is an efficient method for initialisation and setting mode and response time but not for scanning and setting parallelism. Numbers are more useful for this, but they must be converted into suitable strings for output. Also the number must be offset coded. These operations are handled by functions OffCode&(n&) and MakeString$(n&) described in the section 'Demonstration Subroutines' (see below). To scan Z over the full range:

```
FOR n& = -2048 TO 2047
 i& = OffCode&(n&)       'Offset code the number.
 a$ = MakeString$(i&)    'Turn it into a 3 character
                         'string.
 a$ = "I4" + a$ + "P1P0" 'Add buffer control characters
 CALL OutputString(a$)   'Output the string
NEXT n&

CALL OutputString("I0")       'Close the buffers.
```

Setting Parallelism

The X and Y registers are set in the same way, thus to set X to 1234 and Y to -56:

```
Xvalue& = 1234          'Arbitrary values for demonstration
Yvalue& = -56

i& = OffCode&(Xvalue&)
a$ = MakeString$(i&)
a$ = "I1" + a$ + "P1P0" 'Add buffer control characters for X
CALL OutputString(a$)   'Output the string

i& = OffCode&(Yvalue&)
a$ = MakeString$(i&)
a$ = "I2" + a$ + "P1P0" 'Add buffer control characters for Y
CALL OutputString(a$)   'Output the string
CALL OutputString("I0") 'Close the buffers.
```

Demonstration Subroutines

These are useful routines used in the above examples. This one converts an integer into a three digit hex string.

```
FUNCTION MakeString$(n&)

'Convert to a HEX string. If the number is not
'three digits long, it is padded out with leading zero's.
'First ensure number is in range.

i& = n&                       'Buffer variable to prevent
                        'n& being changed.
IF i& < 0 THEN i& = 0
IF i& > 4095 THEN i& = 4095

a$ = HEX$(i&)
IF LEN(a$) = 1 THEN b$ = "00" + a$
IF LEN(a$) = 2 THEN b$ = "0" + a$
IF LEN(a$) = 3 THEN b$ = a$

MakeString$ = b$

END FUNCTION
```

This offset codes an integer for output.

```
FUNCTION OffCode&(n&)

'Offset binary code the input number n&. Check that it is in
'valid range.

i& = n&                       'Buffer variable to prevent
                        'n& being changed.
IF i& < -2048 THEN i& = -2048
IF i& > 2047 THEN i& = 2047
```

```
i& = i& + 2048                'Offset
i& = i& XOR &H800             'Invert MSB
OffCode& = i&

END FUNCTION
```

The following function is useful for decoding strings read back from the CS100.

```
FUNCTION HexToNumber&(a$)

'QuickBasic does not contain any functions for converting
'HEX characters into numbers so one must improvise via the
'ASCII code!

'This general function converts a hexadecimal
'string a$ into a long integer. (Note: Visual Basic can do
 'this directly)

l% = LEN(a$)          'Find the length of the string
n& = 0                'Initialise the output integer.

'Find the code for each character in turn. A zero will be
'inserted if the character is not recognised.

FOR i% = 1 TO l% STEP 1
    num% = ASC(MID$(a$, i%, 1))
    n% = 0
    'Characters A to F
    IF num% >= 65 AND num% <= 70 THEN n% = num% - 55
    'Characters a to f
    IF num% >= 97 AND num% <= 102 THEN n% = num% - 87
    'Characters 0 to 9
    IF num% >= 48 AND num% <= 57 THEN n% = num% - 48
    'Accumulate the result
    n& = 16 * n& + n%
NEXT

'n& is now the integer equivalent of the HEX string.

HexToNumber& = n&

END FUNCTION
```

RS232C and IEEE-488 Interface Definitions

RS232C Interface

Characters are transferred on the RS232C interface as 7 bits with odd parity and one stop bit. Baud rate is 9600. Parity and baud rate can be selected by internal switches, but it is advisable to contact IC

Optical Systems if this is required. The signals used are shown in Table 5.7.

Connector pin number	Signal	Input or Output
2	TxD	Output
3	RxD	Input
4	RTS	Output
6	DSR	Input
7	Ground	-

Table 5.7 RS232 Interface Connector

IEEE-488 Interface

The IEEE-488 is a Talker/Listener without extended address or controller capability. The address can be set with an internal switch but it is advisable to contact IC Optical Systems if this is required. The interface is supplied set to address 8.

The interface recognises EOI as a data terminator but does not assert it during read operations.