Spec4XP

The Ebert-Fastie Spectrometer Control Hardware and Software

F. Sigernes

University Courses on Svalbard (UNIS), Box 156, 9171 Longyearbyen, Norway.

1. Basic optics

This document describes the hardware and software that controls the Ebert – Fastie spectrometers at the Auroral Station in Adventdalen, Svalbard. The main components of the instrument are shown in Fig. 1.

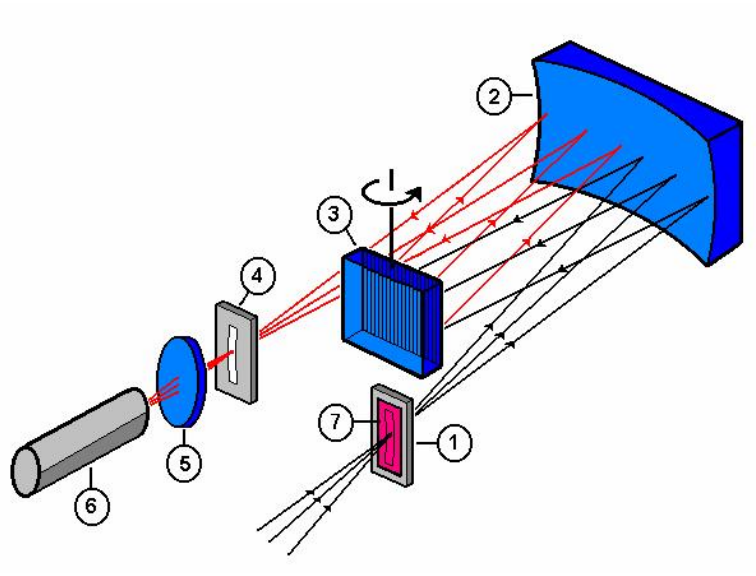


Figure 1. The Ebert-Fastie configuration: (1) entrance slit, (2) concave mirror, (3) plane reflecting grating, (4) exit slit, (5) collector lens, (6) detector, and (7) order sorting cut-off filter.

The principal components of the instruments are one large focal length spherical mirror, one plane reflective diffraction grating and a pair of curved slits. The recorded radiance from the sky is limited by the etendue - the product of the area of the entrance slit and the solid angle field of view. Because of the low intensity of the source, the etendue is made as large as possible. The image of the entrance slit is reflected by one part of the spherical mirror onto the grating. The second part of the mirror focuses the diffracted light from the grating onto the exit slit. When the grating turns, the image of the entrance slit is scanned across the exit slit. A collector lens transfers the output of the exit slit to the front of a photomultiplier tube. The tube is mounted in a thermoelectrically cooled housing and cooled down to -20C. Signals from the tube are amplified and discriminated before sent to the computer’s counting card. Cut-off filters are used in front of the entrance slit to prevent overlapping spectral orders. The field of view of approximately is approximately 5 degrees. Appendix A lists the fundamental equations for this type of optical configuration.

2. Short historical background

The original Ebert-Fastie spectrometer, was constructed by W. G. Fastie at John Hopkins University, Maryland at the beginning of the 70's. Fastie improved the original design of the monochromator made by Hermann Ebert in 1889. In 1978, a 1m and a ½m Ebert-Fastie spectrometer were transferred to the Auroral Station in Adventdalen, Svalbard, from the Geophysical Institute, University of Alaska. One more 1m was installed in 1980. These instruments are named 1m Green, ½m Black and 1m Silver Bullet according to focal length and colour. Since then, the photon counting and computer electronics have been continuously upgraded in order to enhance both the control and performance of the instruments. Furthermore, a ½ m Ebert – Fastie spectrometer (½m White) was moved in 2004 from the Skibotn Observatory in Norway up to Longyearbyen. Data from these instruments are widely published and recognized.

3. Hardware overview

Fig. 2 shows the Ebert – Fastie spectrometer named ½ m White. The main electronics required to run the instrument may be separated in 4 sub categories

1. The detector head: photomultiplier tube (PMT), cooler and preamplifier / discriminator (PAD).
2. The high voltage supply.
3. The grating sweep mechanism.
4. PC with high speed counter card.

A short description of each sub category follows.

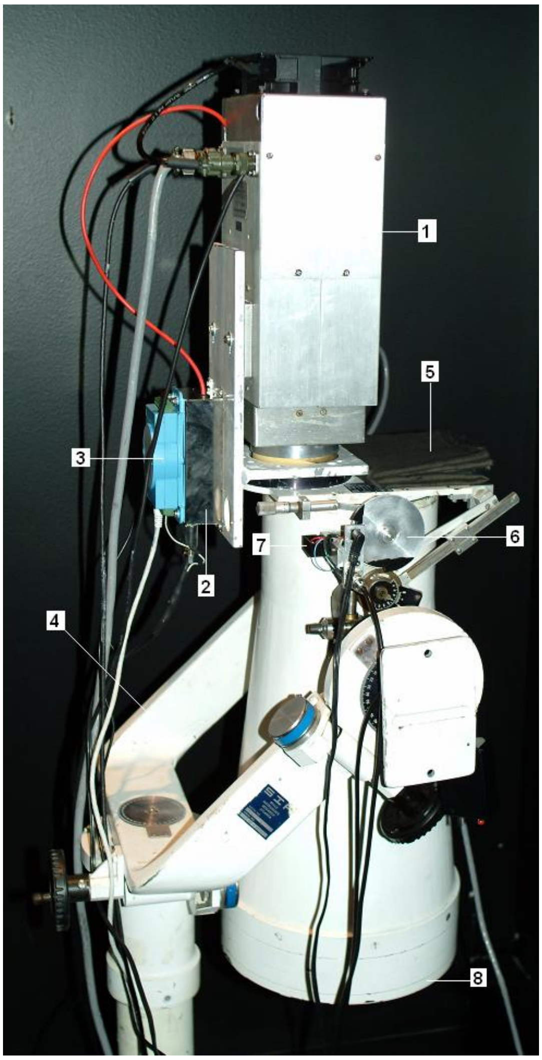


Figure 2. The ½ m White Ebert – Fastie spectrometer. (1) Peltier cooler for PMT, (2) High Voltage supply (HV), (3) HV-controller, (4) tripod, (5) entrance slit plane, (6) Grating cam system, (7) Fiducial sensor, and (8) Back side of concave mirror.

3.1 The detector head

In order to reduce thermo electrical noise or dark current, the photo-multiplicator is cooled using the Peltier technique. Simply stated, Peltier cooling is based on the phenomenon of cooling or absorption of heat at the junction of two rods of metal or semi conductor when a current is made to

Figure 3. Detector: (1) Socket, (2) cooler and (3) photomultiplicator (PMT).

pass through them. In order for thermoelectric cooling devices to be effective, the absorbed heat must be removed from the hot side of the device. In Fig. 2 an air fan is mounted on the top of the housing to blow out / exchange hot air.

The cooler in Fig. 2 is made by the company: Products for Research Inc, model number TE-102TS. Fig. 3 shows the PMT and the socket used. When a photon hits the photo emissive cathode of the tube, it emits a photoelectron into vacuum. The electron is then accelerated and directed to the first electrode (dynode), where it kicks loose a secondary electron. The process continues at the next dynode. Finally, the multiplied result, a train of electrons, is collected by the anode as an output signal. This is illustrated in Fig. 4.

Most of the PMT's we use are from the Hamamatsu Corporation. Some old ones are from Thorn EMI, UK.

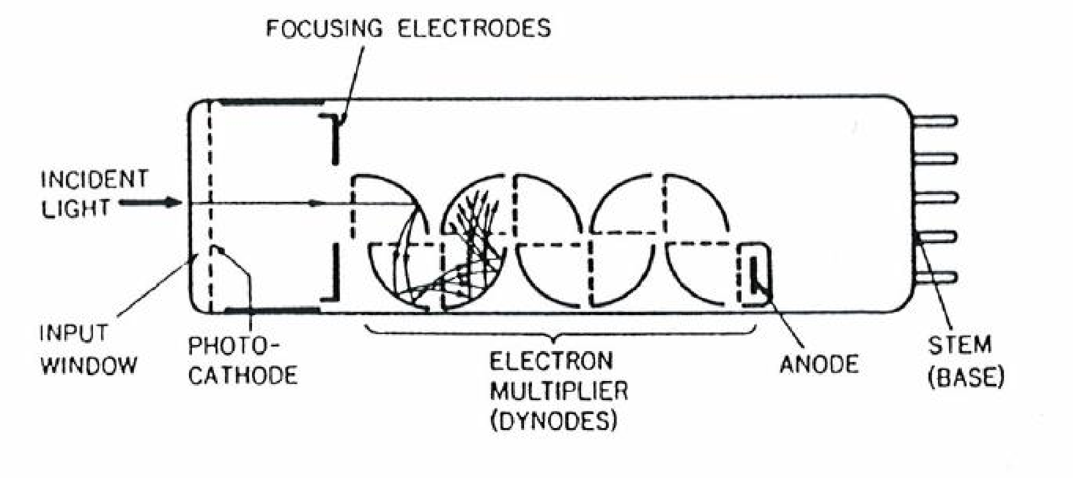


Figure 4. Basic principle of a photomultiplicator (PMT).

The signals from the anode are amplified and discriminated to form a square pulse train. This operation is carried out by a PAD (Pulse Amplifier and Discriminator). The current pulses from the anode of the PMT are converted by the PAD to TTL compatible output pulses that are suitable for PC counter cards. Several types have been used from different manufactures. The Golden bricks are from the former company SpaCom Electronics, or the more recent Silver PADs are from Advanced Research Instrument Corporation, USA.

For the ½ m White spectrometer, the PAD is actually mounted inside the socket, model ADS/ADH/ADP-120. This single printed circuit board comes with the socket from Products for Research Inc. Fig. 5 shows the F-100T Silver PAD and its main specifications.

Max Repetition rate	50 MHz
Sensitivity	160 µV
Input impedance	50 Ω
Input noise level	5 µV
Pulse pair resolution	20 ns
Min. output pulse width	10 ns
Output	TTL
Power supply (# F-100 PS)	+8 – 24 V

Figure 5. The F-100T Preamplifier / Discriminator from Advanced Research Instrument Corporation.

Due to availability and durability, we will use the Silver PAD for future upgrades.

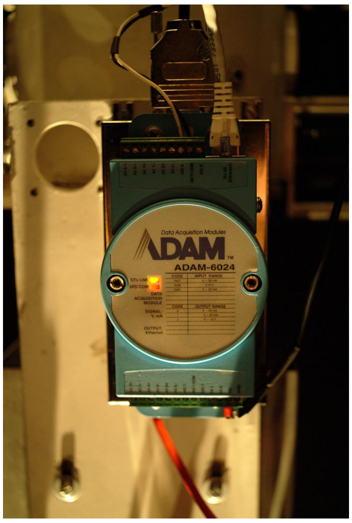


Figure 6. High Voltage (HV)

3.2 The high voltage supply

The high voltage system to the PMT contains the actual high voltage generator, a signal control module and a couple of DC power supplies. The generator is produced by the company Euro Test in Germany (model # CPn 30 405 125). This unit is capable of producing up to -3kV. The output is controlled by a 12 channel multi purpose I/O module from Advantech Co., Ltd. The ADAM-6024 interfaces through the internet through standard IP- based protocols. Fig. 6 shows a close up of the ADAM module mounted on top of the high voltage generator. The specifications and the connection diagram are shown in appendix B and C respectively.

3.3 The grating sweep mechanism

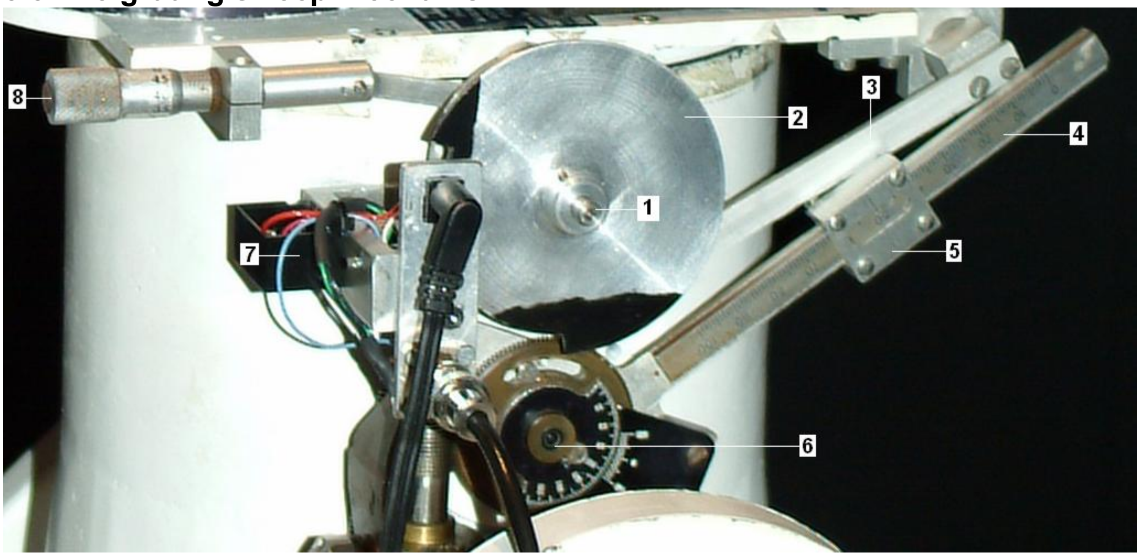


Figure 7. Grating cam system: (1) motor shaft, (2) sinusoidal-shaped rotary cam, (3) intermediate arm, (4) grating arm, (5) moveable pivot, (6) grating shaft, (7) fiducial sensor (start and stop signal of sweep), and (8) adjustable slit width micrometer.

The grating sweep mechanism is variable in position, amplitude and speed. The position of the sweep is determined by the angular position of the grating arm with respect to the grating shaft. The magnitude of the sweep amplitude (spectral range) is varied by an intermediate arm which has a follower and a moveable pivot on which the grating arm rides. This type of cam system is used on both the ½ m White and the 1m Silver Bullet spectrometer. The speed of the grating sweep is controlled by a stepper motor which drives the cam through a reduction gear.

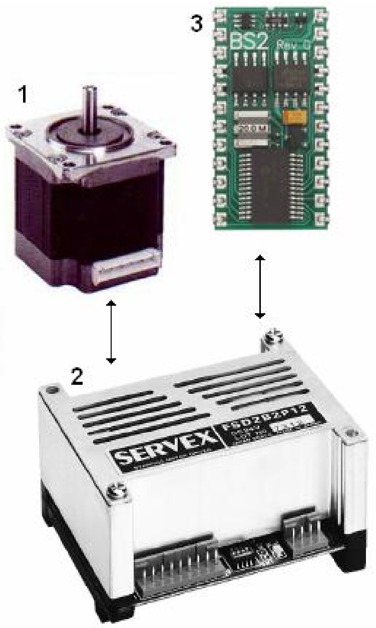


Figure 8. Motor system: (1) stepper motor, (2) driver, and (3) microchip.

The stepper motor and driver system is custom made. The stepper motor is a 2 phase hybrid stepper, model KH56KM2-802 made by Japan Servo Co., Ltd. The driver comes from the same company (Servex FSD2B2P12), and is controlled by a Stamp BS2 microcomputer from Parallax Inc. The specifications on the motor and the driver are found in appendices D and E respectively. The pin assignment for the microcomputer is seen in appendix F. The chip is programmed in a language called PBASIC 2.5. The compiler is called BASIC Stamp Editor (v2.1) and it uploads the source code through a serial RS-232 interface (COM1 on the PC). The source code with comments is listed in appendix H.

The motor is rotating with constant speed. A photodiode triggers a high TTL pulse when the cam moves to the end position of scan. It remains high until the start of the sweep. This signal is called the fiducial and is used to trigger the PC counter card.

3.4 PC with high speed counter card

Figure 9. NI - PCI 6602

The counter card is made by National Instruments (NI). The NI 6602 device is a PCI bus compatible card. It has four 32-bit counter channels and up to 32 lines of individually configurable, TTL/CMOS-compatible digital I/O. The card has a base frequency of 80 MHz and each counter is capable of detecting down to 5 ns wide pulses. The card is installed on a Windows XP operated PC. In addition, a NI SCB-68 connector box is used to access the cards ports. See appendix G for pin assignments.

The basic idea is that the fiducial signal triggers a pulse signal train, where the period of the pulses is the integration time. This pulse train is used as GATE input to the counter channel (SOURCE). The counter counts the number of falling edges that occur on SOURCE between two active edges of the GATE signal. At the completion of the period interval for GATE, the HW Save register latches the counter value for the software read. Fig. 10 shows single-period measurements where the periods of GATE are 3, 7, 10 and 13 SOURCE falling edges.

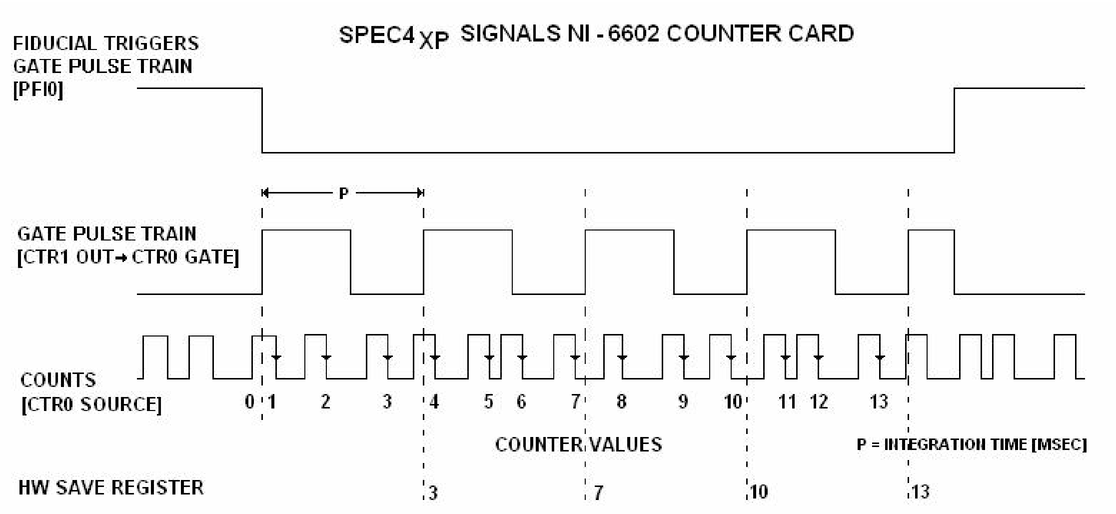


Figure 10. Single period measurement method using the NI-PCI 6602 counter card.

4. Software

4.1 Spec4XP

The software to control the counter card is written in Borland Delphi 5. The routines used are developed over years of operating the spectrometers at the Auroral Station in Adventdalen, Svalbard. The platform is Windows XP. The program is called Spec4XP, named according to its previous ancestors Saas and Spec4 that were compiled for DOS.

Spec4XP uses the National Instruments driver library called NIDAQmx to communicate with the PCI NI-6602 counter card. These drivers are shipped with the card and need to be installed on the host computer. The library is accessible through the DDL file called *nicaiu.dll*. Here is an example on how to declare a function for use in Delphi:

function DAQmxStartTask(task: pointer):longint; stdcall; **external** 'nicaiu.dll';

In order to perform single periodic measurements as mentioned in the previous section, about 14 functions are called from the NIDAQ library. See the source file *Spec4Xpu.pas* for details. Appendix I lists an example on how the code can be written for sampling data.

The program is started by calling the main executable

D:\Spec4Xp\Spec4Xp 60

The input parameter 60 is optional and stands for runtime for a period of 60 minutes. This type of startup is ideal for scheduled operations, where different tasks may be required of the instrument. Fig. 11 shows a screen capture of the program in operation.

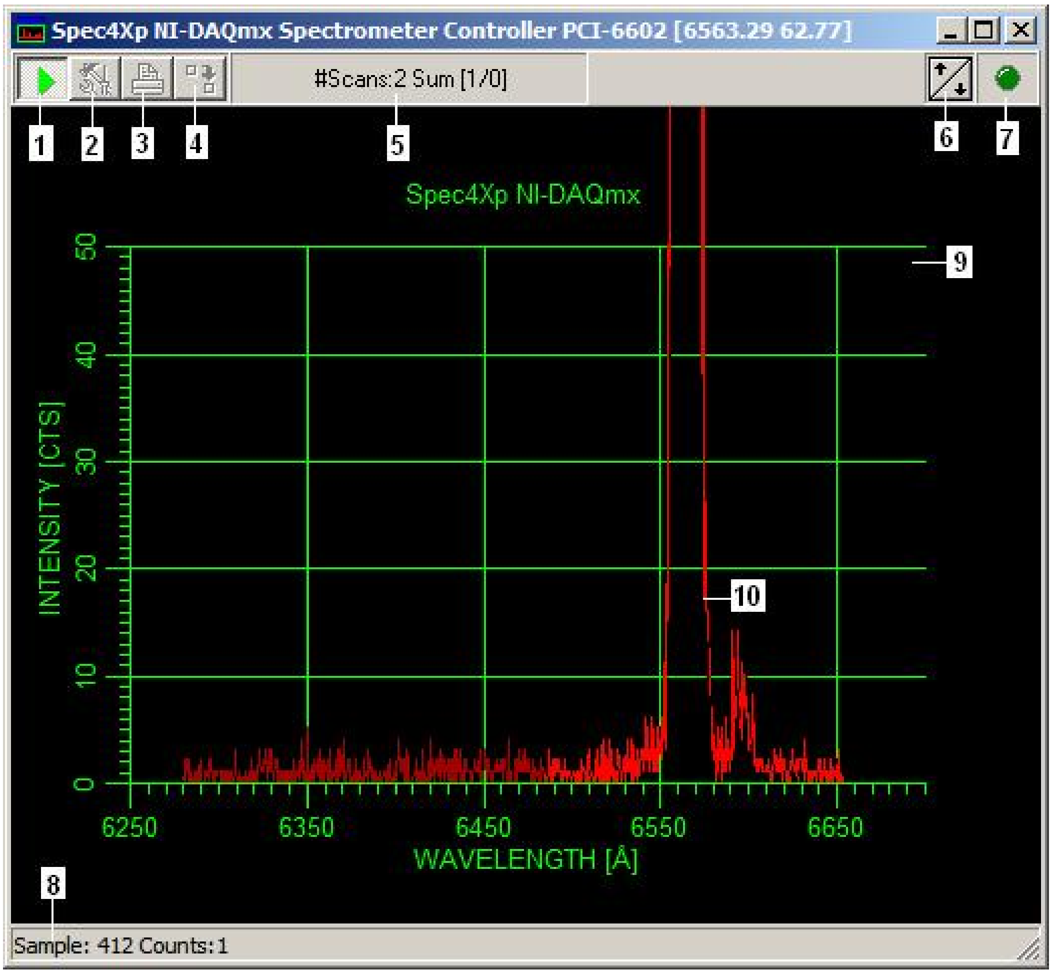


Figure 11. Screen capture of Spec4Xp.exe. (1) is record button, (2) Setup / Configuration of instrument, (3) dumps current graphics to a printer, (4) copies graphics to clipboard (print screen option), (5) status scan counter, (6) scale bar for maximum intensity axis, (7) fiducial indicator – green LOW and red HIGH, (8) status bar for sample vs. counts, (9) axis, and (10) hydrogen lamp spectrum.

The program should be fairly easy to use. An explanation on how to use it is indicated in Fig. 11. The main feature is that it plots wavelength versus intensity in real time. Bright red indicates the current scan and dark red is the previously scan.

All the settings for the instrument are stored in the *Spec4Xp.ini* file. This file is updated every time the program shuts down. The user may edit the file directly or use the setup button for access from the main module. Fig. 12 shows the instrumental configuration menu available to the user.

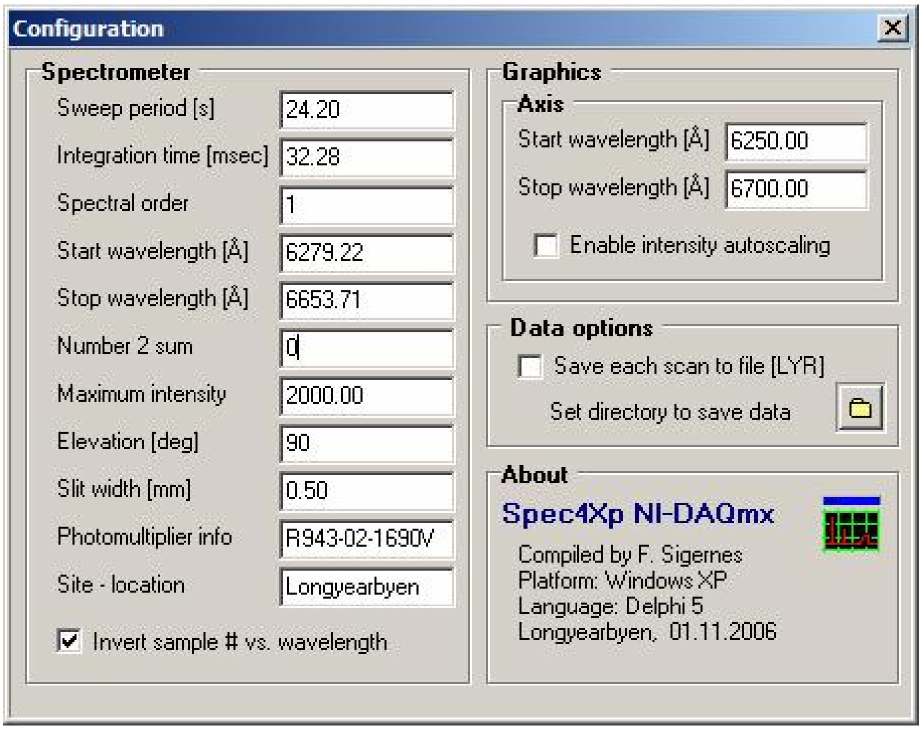


Figure 12. Screen capture of configuration / setup for both program and instrument.

The sweep period divided by the integration time gives the number of samples in one wavelength scan. The motor speed and the gear ratio are therefore important parameters to obtain sufficient sampling per spectral bin (bandpass). The spectral order plays an important role here, as it is part of the grating equation. From this equation we derive the linear dispersion. The theoretical bandpass is then simply linear dispersion multiplied by the slit width. See appendix A for a more detailed description of the basic equations used for an Ebert-Fastie spectrometer.

A simple runtime mean is used to reduce the signal to noise between scans. The *Number 2 sum* does not influence the data saved to disk. Each individual scan is saved to file when the fiducial goes to HIGH. The files are named according to date, sDDMMYY2.LYR and saved in a directory selectable to the user. The format is simple text compatible with our old analyzing software. In addition, the header of each saved file contains observational parameters such as site, elevation, and a photomultiplier info tag / string.

Note that the x-axis of the plot window may have different values for the start and stop wavelengths compared to the actual sampled spectrum. This option is useful if the user want to zoom in on a spectral feature without losing spectral range. Another useful option is auto scaling of the intensities between scans.

The ½ m White is scanning in wavelength in the opposite direction compared to the 1m Silver Bullet spectrometer. This is due to the blaze angle of the grating and which sides of the zero spectral order the instrument is designed to cover. The option called: *Invert sample # vs. wavelength* takes care of this issue.

Wavelength and absolute calibrations are conducted with the program *Spekkis.exe*, which is part of the distribution. The accurate start and stop wavelengths of the scan are calculated by the wavelength calibration module of *Spekkis*.

4.2 HvIP2

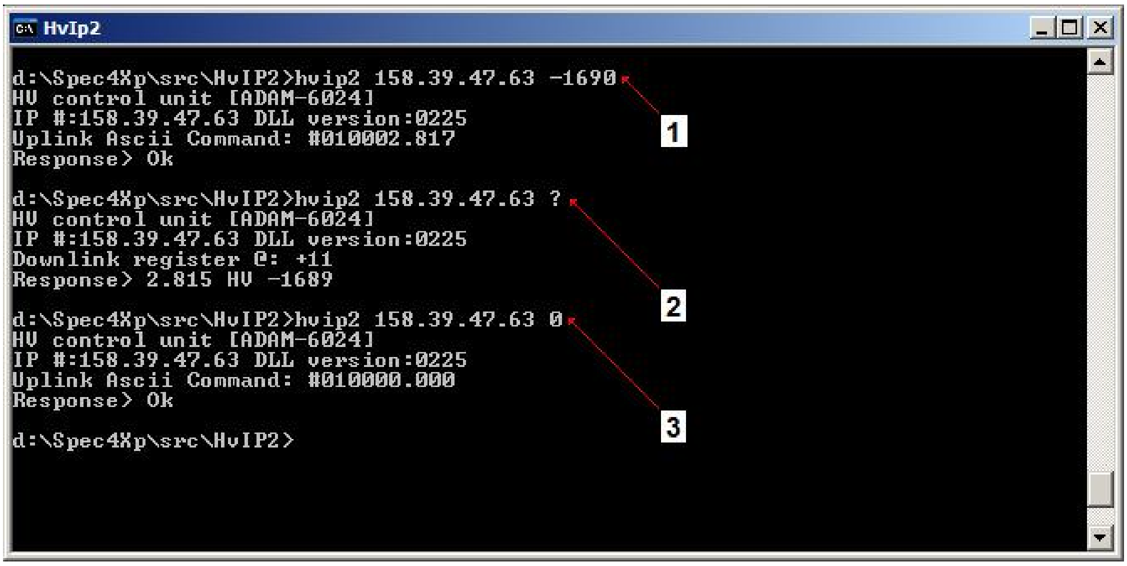


Figure 13. Screen shot of HvIP2 in action. Commands: (1) turns high voltage ON, (2) is status, and (3) turns the high voltage OFF. A four line response follows each command.

The *HVIp2.exe* is a command line program that communicates with the high voltage control module (ADAM-6024) via the internet. The program syntax is

Usage: HvIp2 [IP:] [NEG PMT Voltage or ?].

To turn ON the high voltage to -1690V, simply type on the Command Prompt:

HvIp2 158.39.47.63 -1690

Correspondingly, the high voltage is turn OFF by the command

Hvlp2 158.39.47.63 0

You request the status by typing

Hvlp2 158.39.47.63 ?

Note that in the above examples the IP number 158.39.47.63 is just used for testing of the system. The program basically converts the input strings to the ASCII or the Modbus / TCP protocols used by the manufacturer. The Delphi 5 source file *HvIP2.dpr* communicates with the Winsock API through the driver files *Adamtcp.pas* and *Adamtcp.dll* that comes with the unit. Two command files *hvon.bat* and *hvoff.bat* use the above program to turn the high voltage ON and OFF in incremental voltage steps, respectively. Fig. 13 shows a screenshot of the program in action.

IMPORTANT
Turn the blue button of DC power supply to the high voltage unit OFF during troubleshooting or faulty conditions! Make sure that the ADAM module is operative and working before turning the power ON again (+12.5 VDC).

4.3 First test of Spec4Xp with ½m White spectrometer

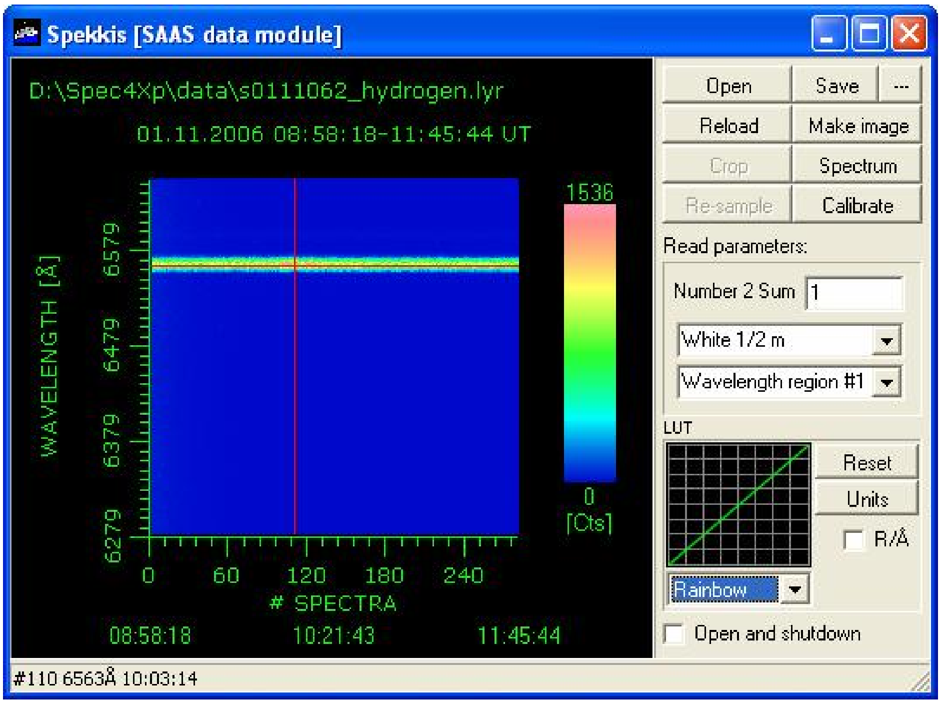


Figure 14. ½m White spectrogram of hydrogen gas lamp.

The Spec4Xp system was tested for the first time with the ½m White spectrometer in the calibration laboratory at UNIS. Fig. 14 shows the wavelength calibrated spectra of a hydrogen lamp. The system appears run well, but it needs to be tested over at least one auroral season in order to be sure of operational stability and performance.

Manufactory list

Products for Research Inc.
88 Holten Street, Danvers, MA 01923, USA
Phone: (978)774-3250 – Fax: (978) 762-3593
http://www.photocool.com/

Hamamatsu Photonics K. K.
325-6, Sunayama - cho, Hamamatsu City, Shizuoka Pref., 430-8587, Japan
Phone: (81)-53-452-2141 – Fax: (81)-53-456-7889
http://www.hamamatsu.com

Advanced Research Instruments Corporation
PO Box 7427
Golden CO 80403 USA
http://www.aricorp.com

Euro Test
ET System electronic GmbH
Haupstr. 119 – 121
D-68804, Altlu h eim, Germany.
Tel.: +49 (0)6205 3948-0 - Fax: +49 (0)6205 375 60
http://www.ETSGmbH.de

Advantech Co., Ltd.
No. 1, Alley 20, Lane 26
Rueiguang Road, Neihu District
Taipei 114, Taiwan, R. O. C.
http://www.advantech.com

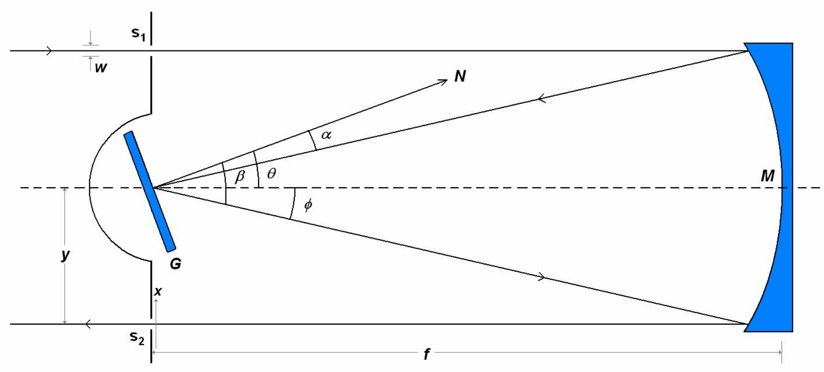
Japan Servo Co.,Ltd.
7, Kanda Mitoshirocho, Chiyodaku
Tokyo 101-0053 Japan
Tel.3(3292)3506~8
Fax.3(3292)3509
http://www.japanservo.com

Parallax Inc.
599 Menlo Drive, #100
Rocklin, CA 95765, USA
Telephone: (916) 624-8333
Fax: (916) 624-8003
http://www.parallax.com/

National Instruments
11500 North Mopac Expressway
Austin, Texas 78759-3504 USA
Tel: 512 794 0100
http://www.ni.com/

APPENDIX A

Basic equations for an Ebert-Fastie spectrometer



N – grating normal
θ – grating angle
ϕ – constant
tan $\phi = y / f$
f – focal length
α – incident angle
β – diffracted angle
y – ½ slit – slit distance
a – groove spacing
n – spectral order
w – slit width

Figure 1. Optical diagram Ebert- Fastie spectrometer. G is plane reflective grating, S_1 entrance slit, S_2 exit slit, and M concave mirror.

The grating equation is

$$n\lambda = a\,(\sin\alpha + \sin\beta)\text{, where } \alpha = \theta - \phi \text{ and } \beta = \theta + \phi .$$

Then $n\lambda = a\left[(\sin\theta\cos\phi - \sin\phi\cos\theta) + (\sin\theta\cos\phi + \sin\phi\cos\theta)\right]$ or

$$\Rightarrow \quad n\lambda = 2a\,\sin\theta\cos\phi .$$

Angular dispersion is

$$\frac{d}{d\beta}(n\lambda) = a\,\cos\beta ,$$

and since $dx = f\,d\beta$ then linear dispersion becomes

$$\frac{d\lambda}{dx} = \frac{d\lambda}{d\beta\, f} = \frac{a\cos\beta}{n\,f} = \frac{a\cos(\theta+\phi)}{n\,f}$$

The theoretical bandpass of the instrument is then defined as

$$BP = FWHM = \frac{d\lambda}{dx} \times w = \frac{a\cos(\theta+\phi)}{n\,f} \times w.$$

APPENDIX B

CPx)1 30 405 12 5

HV-Modul der CPS Serie

Technische Daten

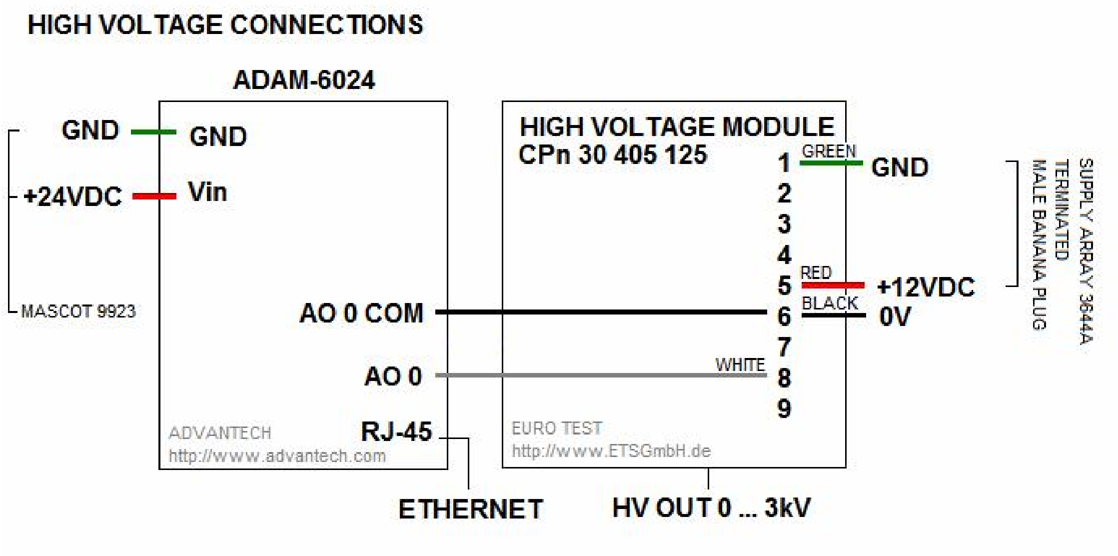
V_{OUT}	)1x=p: 0 bis 3 kV (bezogen auf GND))1x=n: 0 bis - 3 kV
I_{OUTmax}	4 mA
V_{IN}	11,5 bis 15,5 V-DC
I_{IN}	< 1,5 A (V_{OUT}= 0 ; I_{OUT}= 0: < 100 mA)
Steuerung mit	V_{SET} = 0 bis 5 V
Monitoring mit	V_{MON} = 0 bis 5 V
Ripple	typ: 60 mV_{P-P} max.: 150 mV_{P-P}
Stabilität	$\Delta V_{OUT} / \Delta V_{IN}$: $< 1 * 10^{-4} * V_{OUTmax}$ Leerlauf/Vollast: $< 2 * 10^{-4} * V_{OUTmax}$
Temperaturkoeffizient	$< 1 * 10^{-4}/_K$
Betriebstemp.-bereich	0 . . . +50 °C
Lagertemp.-bereich	-20 . . . +60 °C
HV-Ausgang	- Lemo HV-Kabel 9 kV, geschirmt (LEMO 9106330) - Länge = 600 mm - überlast und kurzschlußfest

9-poliger D-Sub Stecker

PIN	Name	Beschreibung
1	PWR_0V	Power 0 V (verbunden mit PIN 6, GND und Gehäuse)
2	V_I_{MON}	Monitorspannung entsprechend I_{OUT} I_{OUT}= 0 bis I_{OUTmax} ⇒ V_{2-6} = 0 bis V_{MON}
3	INH	INHIBIT (TTL-Pegel, LOW=aktiv ⇒ V_{OUT} = 0)
4	V_I_{SET}	Hardwarestrom-Limit: V_{4-6} = 0 bis V_{SET} (R_i = 10 kΩ gegen V_{REF}) ⇒ I_{OUT} = 0 bis I_{OUTmax} n.c. ⇒ I_{OUTmax} ist möglich
5	PWR_+	+ V_{IN}
6	V_{SET}_0V	Signal 0 V (verbunden mit PIN 1, GND und Gehäuse)
7	V_V_{MON}	Monitorspannung entsprechend V_{OUT} V_{OUT}= 0 bis V_{OUTmax} ⇒ V_{7-6} = 0 bis V_{MON}
8	V_V_{SET}	Spannungssteuerung: V_{8-6} = 0 bis V_{SET} ⇒ V_{OUT} = 0 bis V_{OUTmax}
9	V_{REF}	V_{9-6} = 5 V (1 mA) Interne Ref.-spannung für ext. Poti (Schleifer an V_V_{SET} und/oder V_I_{SET})

ET System electronic GmbH
Hauptstr. 119-121
D – 68804 Altlußheim Germany
Email: info@ETSGmbH.de
http://www.ETSGmbH.de
Tel ++ 49 (0)6205 / 39 48 - 0
Fax ++ 49 (0)6205 / 37 560

APPENDIX C


HIGH VOLTAGE CONNECTIONS
ADAM-6024
GND
GND
+24VDC
Vin
MASCOT 9923
AO 0 COM
AO 0
ADVANTECH
http://www.advantech.com
RJ-45
ETHERNET
HIGH VOLTAGE MODULE
CPn 30 405 125
1
2
3
4
5
6
7
8
9
GREEN
GND
RED
+12VDC
BLACK
0V
WHITE
EURO TEST
http://www.ETSGmbH.de
HV OUT 0 ... 3kV
SUPPLY ARRAY 3644A
TERMINATED
MALE BANANA PLUG

APPENDIX D

2–Phase Hybrid Stepping Motor 1.8°

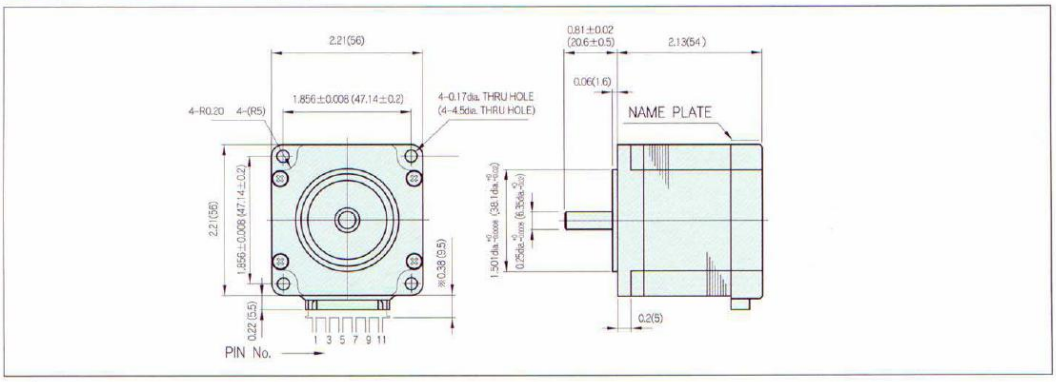
KH56 series 800 type

HIGH TORQUE, LOW VIBRATION AND LOW NOISE

■ STANDARD SPECIFICATIONS

MODEL	UNIT	KH56KM2			
		-801	-802	-803	-851
DRIVE METHOD	———	UNI–POLAR			BI–POLAR
NUMBER OF PHASES	———	2			2
STEP ANGLE	deg./step	1.8			1.8
VOLTAGE	V	2.4	3.7	6.8	~~4.05~~ 4,35
CURRENT	A/PHASE	3.0	2.0	1.0	1.5
WINDING RESISTANCE	Ω/PHASE	0.8	1.85	6.8	2.9
INDUCTANCE	mH/PHASE	1.1	3.3	13.5	10.7
HOLDING TORQUE	kgf · cm	8.5	8.5	8.5	10.0
	oz · in	118	118	118	139
DETENT TORQUE	gf · cm	400	400	400	400
	oz · in	5.6	5.6	5.6	5.6
ROTOR INERTIA	g · cm²	270	270	270	270
	oz · in²	1.48	1.48	1.48	1.48
WEIGHTS	g	650	650	650	650
	lb	1.4	1.4	1.4	1.4
INSULATION CLASS	———	JIS Class E (120℃ 248° F) (UL VALUE : CLASS B 130℃ 266° F)			
INSULATION RESISTANCE	———	500VDC 100MΩ min.			
DIELECTRIC STRENGTH	———	500VAC 50HZ 1min.			
OPERATING TEMP. RANGE	℃	0 to 50			
ALLOWABLE TEMP. RISE	deg.	70			

■ DIMENSIONS unit = inch (mm)



This is our new series 800 Type, which maintains the high torque performance of our conventional 500 Type and lowers vibration and noise .

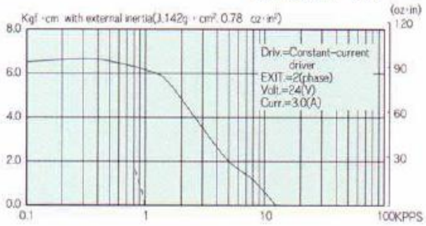
- High efficiency and high torque have been achieved through our intensive research on magnetic circuitry.
- A unique tooth profile has been employed through the development of a new proven theory to achieve low vibration and low noise.

—— PULL-OUT
········ PULL-IN

■ TORQUE CHARACTERISTICS vs. PULSE RATE

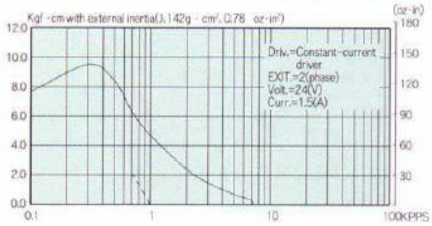
UNI-POLAR

KH56KM2-801

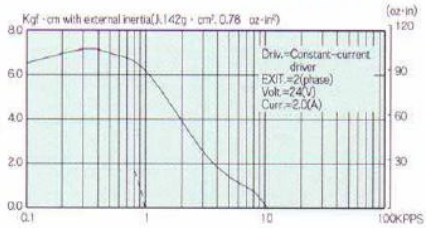


BI-POLAR

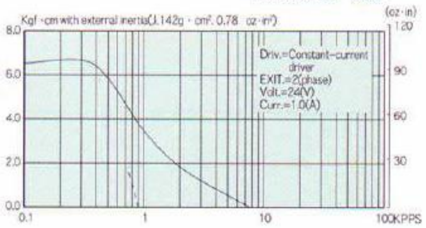
KH56KM2-851



KH56KM2-802

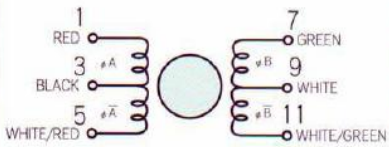


KH56KM2-803



■ CONNECTION DIAGRAMS

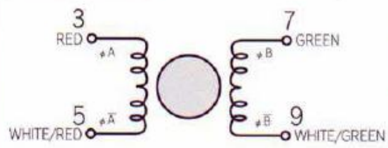
UNI-POLAR (-801,2,3)



EXCITATION SEQUENCE

STEP	1	2	3	4
RED	−			−
GREEN	−	−		
WHITE/RED		−	−	
WHITE/GREEN			−	−
BLACK	+	+	+	+
WHITE	+	+	+	+

BI-POLAR (-851)

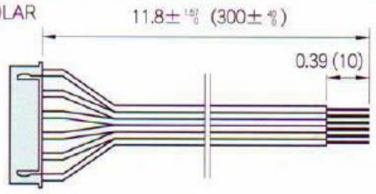


EXCITATION SEQUENCE

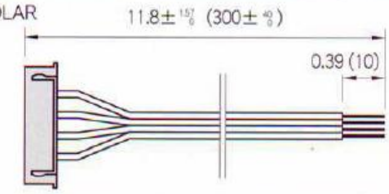
STEP	1	2	3	4
RED	+	+	−	−
GREEN	−	+	+	−
WHITE/RED	−	−	+	+
WHITE/GREEN	+	−	−	+

■ CONNECTION CABLE TO MOTOR unit = inch (mm)

UNI-POLAR



BI-POLAR



APPENDIX E

2-Phase Hybrid Stepping Motor Driver

HIGH TORQUE, SILENT ROTATION
SERVEX FSD2B2P12-01 DC24V

Features

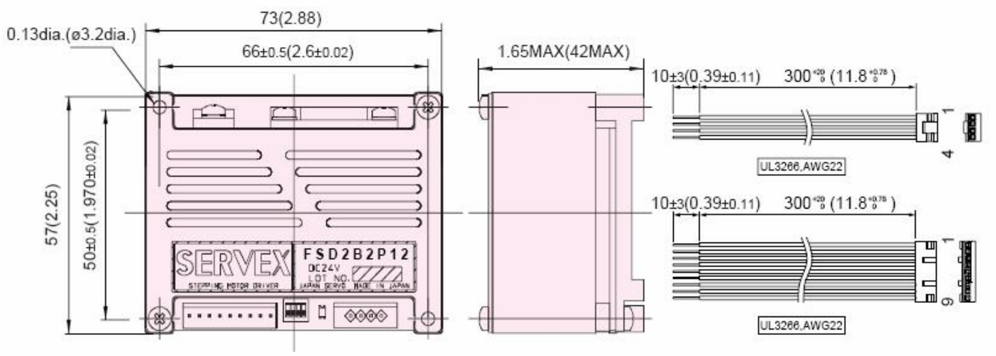
1. Ultra-compact driver measuring a mere 2.2 x 2.9 x 1.7 inches.
2. Bi-polar fixed-current driver.
3. Micro-stepping feature may be used to be selected from any one of 1/1 (full-step), 1/2 (micro-step), and 1/4 (micro-step)settings.
4. Through the use of 3-bit external signals, electric current settings may be specified to any one of a range of 8 different settings from 0.41-2A/phase power.
5. Input commands may be selected from either of direction-of-rotation separate serial

Applicable motors

KH42HM2-951, 961
KH42JM2-951, 961
KH42KM2-951, 961
KH56JM2-851, 951, 961
KH56KM2-851, 951, 961
KH56QM2-851, 951, 961

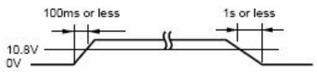
KH39EM2-851
KH39FM2-851
KH39GM2-851

Dimensions



Power supply specifications

Motor Power supply voltage(VM) : 10.8V~33.0V



Motor output current; About 2A max.(different dependeing on the drive parameters of the motor being used)

Connector specifications

	FSD2U2P12-01 side	User side		Maker
	Maker Model	Applicable Housing	Applicable terminal(real)	
CN3	IL-G-9P-S3T2-E	IL-G-9S-S3C2	IL-G-C2-SC-10000	J.A.E
CN2	IL-G-6P-S3T2-E	IL-G-6S-S3C2	IL-G-C2-SC-10000	J.A.E

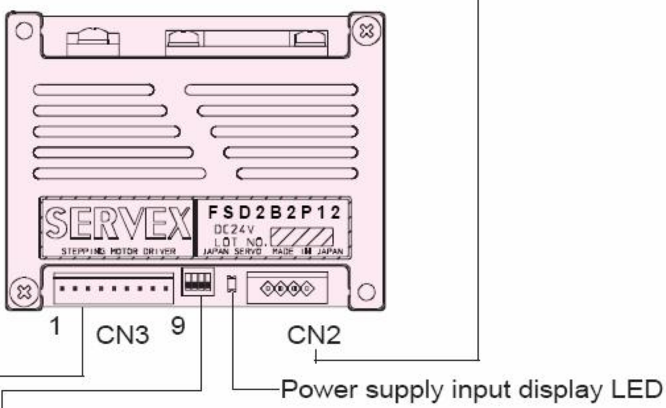
Required operating environment conditions

	In operation	At rest	Comments
Ambient temperature (°C)	0~+50	-20~60	
Ambient humidity(%)	35~85	35~85	Non condensation

Functions, Setting and Connections

Connector Name	Pin No.	Signal Name	Function							
CN3	1	VM	Motor power supply(to be connected to 12-30V power supply)							
	2	P.GND	Motor power supply GND							
	3	CW	CW directional drive pulse and serial pulse signal input							
	4	CCW	CCW directional drive pulse and direction-of-rotation signal input							
		Motor current (A)	0.41	0.64	0.86	1.09	1.32	1.55	1.77	2.00
	7	C0	H	L	H	L	H	L	H	L
	6	C1	H	H	L	L	H	H	L	L
	5	C2	H	H	H	H	L	L	L	L
	8	H.OFF	H. off (used to cut power to motor)							
	9	S.GND	Signal ground							

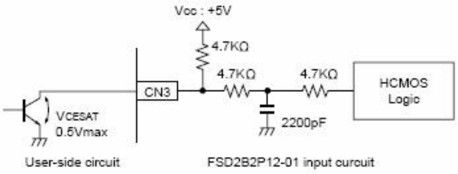
Connector Name	Pin No.	Signal Name	Function
CN2	1	A	Motor current(A)
	2	Ā	Motor current(Ā)
	3	B	Motor current(B)
	4	B̄	Motor current(B̄)



Switch No.	Switch Name		Function		Switch position and operation: OFF	Switch position and operation: ON
1	SEL		Pulse input method settings		CW / CCW	Serial Pulse / DIR signal
2	SAVE		Selection of automatic motor power save feature		save	do not save
3	Step angle settings	Divisions	1 / 2	1 / 1	1 / 4	1 / 2
		MS0	ON	OFF	ON	OFF
4		MS1	ON	ON	OFF	OFF

Input circuit

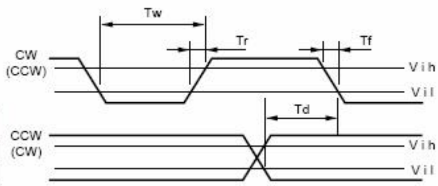
CW, CCW, C0, C1, C2, H. OFF



Input signal specifications

Item	Signal	Specification: MIN	Specification: MAX
High level input voltage	Vih(V)	3.5	5.3
Low level input voltage	Vil(V)	0.0	0.8
Rise time	Tr(μs)	–	25
Fall time	Tf(μs)	–	15
Input pulse range	Twl(μs)	18	–
Direction of rotation change timing	Td(μs)	10	–

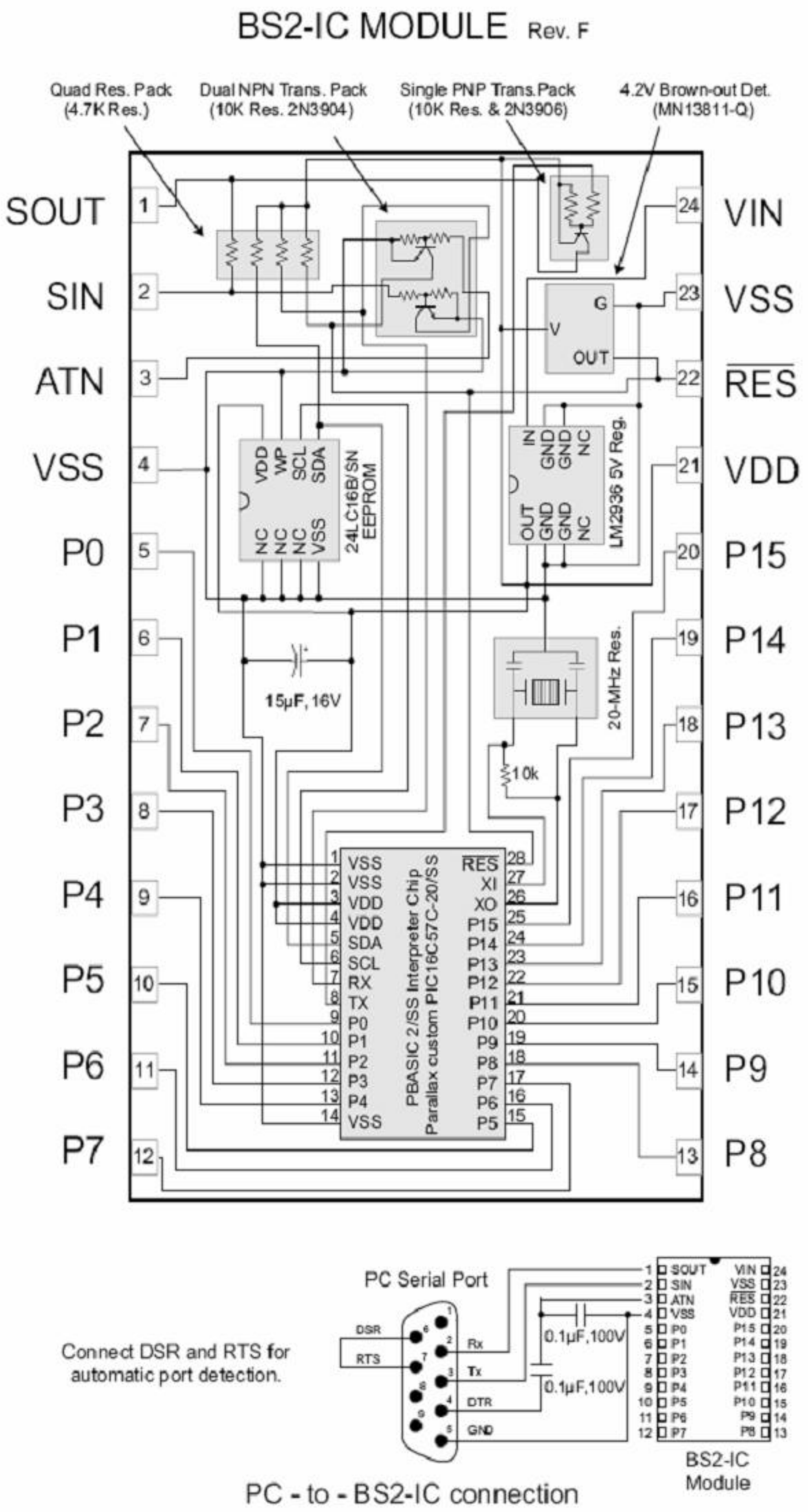
Note)Specified the voltage waveform between the user circuit ground and the FSD2B2P12-01 terminal



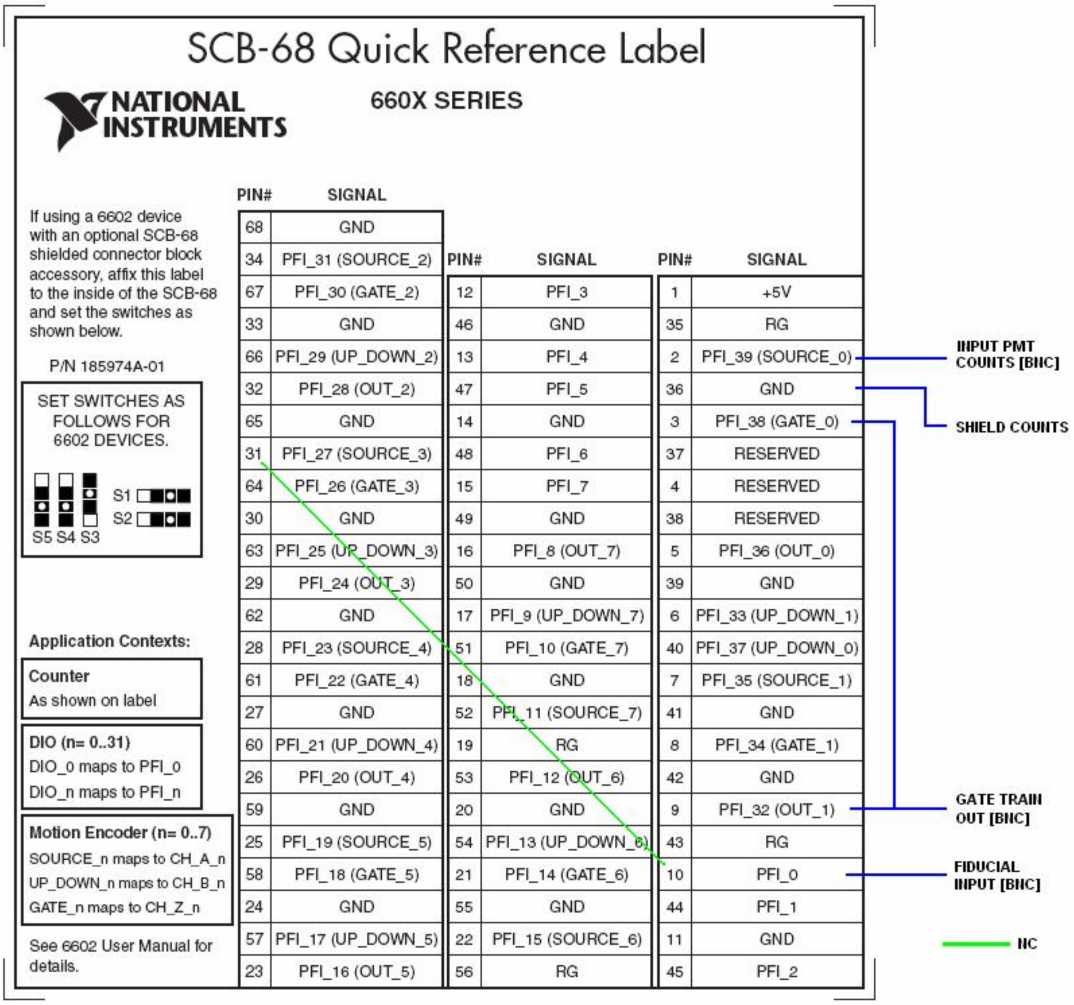
Connector specifications

	FSD2B2P12-01 side: Maker Model	User side: Applicable Housing	User side: Applicable terminal(real)	Maker
CN3	IL-G-9P-S3T2-E	IL-G-9S-S3C2	IL-G-C2-SC-10000	J.A.E
CN2	IL-G-4P-S3T2-E	IL-G-4S-S3C2	IL-G-C2-SC-10000	J.A.E

APPENDIX F


BS2-IC MODULE Rev. F
Quad Res. Pack (4.7K Res.)
Dual NPN Trans. Pack (10K Res. 2N3904)
Single PNP Trans.Pack (10K Res. & 2N3906)
4.2V Brown-out Det. (MN13811-Q)
SOUT
SIN
ATN
VSS
P0
P1
P2
P3
P4
P5
P6
P7
VIN
VSS
RES
VDD
P15
P14
P13
P12
P11
P10
P9
P8
24LC16B/SN EEPROM
LM2936 5V Reg.
15µF, 16V
20-MHz Res.
10k
PBASIC 2/SS Interpreter Chip
Parallax custom PIC16C57C-20/SS
PC Serial Port
Connect DSR and RTS for automatic port detection.
DSR
RTS
Rx
Tx
DTR
GND
0.1µF,100V
0.1µF,100V
BS2-IC Module
PC - to - BS2-IC connection

APPENDIX G



SCB-68 Quick Reference Label

NATIONAL INSTRUMENTS

660X SERIES

If using a 6602 device with an optional SCB-68 shielded connector block accessory, affix this label to the inside of the SCB-68 and set the switches as shown below.

P/N 185974A-01

SET SWITCHES AS FOLLOWS FOR 6602 DEVICES.

S1 S2 S5 S4 S3

Application Contexts:

Counter
As shown on label

DIO (n= 0..31)
DIO_0 maps to PFI_0
DIO_n maps to PFI_n

Motion Encoder (n= 0..7)
SOURCE_n maps to CH_A_n
UP_DOWN_n maps to CH_B_n
GATE_n maps to CH_Z_n

See 6602 User Manual for details.

PIN#	SIGNAL
68	GND
34	PFI_31 (SOURCE_2)
67	PFI_30 (GATE_2)
33	GND
66	PFI_29 (UP_DOWN_2)
32	PFI_28 (OUT_2)
65	GND
31	PFI_27 (SOURCE_3)
64	PFI_26 (GATE_3)
30	GND
63	PFI_25 (UP_DOWN_3)
29	PFI_24 (OUT_3)
62	GND
28	PFI_23 (SOURCE_4)
61	PFI_22 (GATE_4)
27	GND
60	PFI_21 (UP_DOWN_4)
26	PFI_20 (OUT_4)
59	GND
25	PFI_19 (SOURCE_5)
58	PFI_18 (GATE_5)
24	GND
57	PFI_17 (UP_DOWN_5)
23	PFI_16 (OUT_5)

PIN#	SIGNAL
12	PFI_3
46	GND
13	PFI_4
47	PFI_5
14	GND
48	PFI_6
15	PFI_7
49	GND
16	PFI_8 (OUT_7)
50	GND
17	PFI_9 (UP_DOWN_7)
51	PFI_10 (GATE_7)
18	GND
52	PFI_11 (SOURCE_7)
19	RG
53	PFI_12 (OUT_6)
20	GND
54	PFI_13 (UP_DOWN_6)
21	PFI_14 (GATE_6)
55	GND
22	PFI_15 (SOURCE_6)
56	RG

PIN#	SIGNAL
1	+5V
35	RG
2	PFI_39 (SOURCE_0)
36	GND
3	PFI_38 (GATE_0)
37	RESERVED
4	RESERVED
38	RESERVED
5	PFI_36 (OUT_0)
39	GND
6	PFI_33 (UP_DOWN_1)
40	PFI_37 (UP_DOWN_0)
7	PFI_35 (SOURCE_1)
41	GND
8	PFI_34 (GATE_1)
42	GND
9	PFI_32 (OUT_1)
43	RG
10	PFI_0
44	PFI_1
11	GND
45	PFI_2

APPENDIX H

```
' {$STAMP BS2}
Btn VAR Byte
Directn1  VAR Byte  ' Hjelpevariabel for display av retning
SLEP      VAR Word  ' Ventetid mellom hver puls i millisekund
cSLEP     VAR Word  ' Ventetid avhengig av retning
DiffSpeed CON 1     ' Dersom 1 kjør retur med speed, ellers lik hastighet
RSpeed    CON 1     ' Returhastighet
Baud96    CON 84    ' Kommunikasjonshastighet mellom stamp og PC
Duration  CON 7     ' 2*Duration = varighet på pulsen i mikrosekund
Retn      CON 0     ' Pin som retning til motoren angis på. HIGH = CW / LOW =CCW
Puls      CON 1     ' Pin for pulsgenerering til motoren
C2        CON 2     ' C0-C2 brukes for å sette fasestrømmen på motoren
C1        CON 3     ' Se driver dokumentasjon.
C0        CON 4     ' Driver: Servex FSD2B2P12 (Kjøpt fra Aratron.no, Roar Haukenes)
POW       CON 5     ' For å kutte effekt til motoren; Pow=1 => Motor off
PCW       CON 8     ' Hvis denne pinnen er satt, så roterer motoren med klokka
PCCW      CON 9     ' Hvis denne pinnen er satt, så roterer motoren mot klokka
                    ' Hvis verken PCW eller PCCW så kuttes strømmen til motoren
' Strømstyring
C0_set  VAR Byte   : C0_set=0                ' P2
C1_set  VAR Byte   : C1_set=0                ' P3
C2_set  VAR Byte   : C2_set=1                ' P4
' Pin0 --> Retning
' Pin1 --> Pulstog
' Pin2 --> C_0
' Pin3 --> C_1
' Pin4 --> C_2
' Pin5 --> Motor on/off
' Pin6 --> Bryter start/stopp
DIRS = %0000000000111111 ' 1 -> Output pin
OUTS = %0000000000000000 ' Setter alle initiert til 0
' Setter noen pinner
OUT4 = C0_set
OUT3 = C1_set
OUT2 = C2_set
Btn = 0
SEROUT 16, Baud96, ["Welcome Stamp II Serial stepper!",13] SEROUT 16, Baud96,
["K. Heia and A.H Sivertsen Fiskeriforskning 2004",13] SEROUT 16, Baud96,
["Example: Delay [ms]> 1",13]
SEROUT 16, Baud96, ["Delay [ms]> "]
SERIN  16, Baud96, [DEC SLEP]
cSlep=Slep
FirstRun:
OUT5 = 1
PAUSE 10
IF IN6=0 THEN FirstRun
DEBUG  "Wait for Start run ",13
WaitForRun:
IF IN6=0 THEN StartRunning
GOTO WaitForRun
StartRunning:
PAUSE 10
IF IN6=0 THEN StartRunning
' Sjekker retning
Slep=cSlep
IF IN8=0 THEN CW
IF IN9=0 THEN CCW
GOTO FirstRun ' Hvis ingen retning satt, hopp til FirstRun
CCW:
OUT5 = 0
LOW Retn  :  Directn1="-"
DEBUG "Move Counter Clock wise",CR
GOTO KeepRunning
CW:
OUT5 = 0
HIGH Retn :  Directn1="+"
DEBUG "Move clock wise",CR
GOTO KeepRunning
KeepRunning:
PULSOUT Puls, Duration
PAUSE SLEP
IF IN6=0 THEN FirstRun
GOTO KeepRunning
```

APPENDIX I

```
Procedure SampleDataExample;
var freq:double;
    Gate_puls:TaskHandle;
    cts_hnd: TaskHandle;
    cts: LongWord;
    Dig_hnd:TaskHandle;
    data:array[0..7] of byte;
    read,bytesPerSamp:LongInt;
    Cts1,Cts2:LongWord;
    Counts:LongWord;
begin
    loop:=true;
    Exposure_time:=65.54;
    freq:=1000/Exposure_time;
    //Fiducial status on PFI0
    Dig_hnd := nil;
    DAQmxCreateTask('',addr(Dig_hnd));
    DAQmxCreateDIChan(Dig_hnd,'Dev1/port0/line0:7','',DAQmx_Val_ChanForAllLines);
    DAQmxStartTask(Dig_hnd);
    //Gate Train triggered by PFI0 on CTR1
    Gate_puls  := nil;
    DAQmxCreateTask('',addr(Gate_puls));
    DAQmxCreateCOPulseChanFreq(Gate_puls,'Dev1/ctr1','',
                           DAQmx_Val_Hz,DAQmx_Val_Low,0.0,freq,0.50);
    DAQmxSetPauseTrigType(Gate_puls,DAQmx_Val_DigLvl);
    DAQmxSetDigLvlPauseTrigSrc(Gate_puls,'/Dev1/PFI0');
    DAQmxSetDigLvlPauseTrigWhen(Gate_puls, DAQmx_Val_High);
    DAQmxCfgImplicitTiming(Gate_puls,DAQmx_Val_ContSamps,1000);
    DAQmxStartTask(Gate_puls);
    //CTR0 WITH GATE FROM PFI32
    cts_hnd:=nil;
    DAQmxCreateTask('',addr(cts_hnd));
    DAQmxCreateCICountEdgesChan(cts_hnd,'Dev1/ctr0','',DAQmx_Val_Falling,0,
                            DAQmx_Val_CountUp);
    DAQmxCfgSampClkTiming(cts_hnd,'/Dev1/PFI32',1000.0,DAQmx_Val_Rising,
                      DAQmx_Val_ContSamps,1000);
    DAQmxStartTask(cts_hnd);
    Cts:=0; Cts1:=0; Cts2:=0;
    DataCounter:=0;
    //Main loop
    repeat
      DAQmxReadDigitalLines(Dig_hnd,1,10.0,DAQmx_Val_GroupByChannel,
                        addr(data),8,addr(read),addr(bytesPerSamp),nil);
      if data[0] = 0 then
      begin
       Cts1:=cts;
       DAQmxReadCounterScalarU32(cts_hnd,10.0,addr(cts),nil);
       Cts2:=Cts;
       Counts:=Cts2-Cts1;
       //Here I want to do realtime plotting.
      end else
      begin
         //Here I plan to save the data
         datacounter:=0;
      end;
      Application.ProcessMessages;
    until (not loop);
    //END of LOOP (terminated by Keystroke)
    if (cts_hnd <> NULL) then
    begin
        DAQmxStopTask(cts_hnd);
        DAQmxClearTask(cts_hnd);
    end;
    if (Gate_puls <> NULL) then
    begin
        DAQmxStopTask(Gate_puls);
        DAQmxClearTask(Gate_puls);
    end;
    if (Dig_hnd <> NULL) then
    begin
        DAQmxStopTask(Dig_hnd);
        DAQmxClearTask(Dig_hnd);
    end;
end;
```

APPENDIX J

Network of Ebert-Fastie Spectrometers on Svalbard

Instrument name	Location	HvIP2	PC
1 m Green	Longyearbyen	158.39.49.204	158.39.49.102
1 m Silver	Longyearbyen	158.39.49.203	158.39.49.107
½ m White	Longyearbyen	158.39.49.202	158.39.49.201
½ m Black	Ny-Ålesund *	-	193.156.10.172

Mask: 255.255.255.0 Gateway: 158.39.49.1 DNS: 158.39.46.248 / 158.39.47.4

*** Web Camera in Ny-Ålesund**
IP: 193.156.10.173 Mask: 255.255.255.192 Router: 193.156.10.129

Name: protcam.nyaal.npolar.no DNS: 158.39.46.248 / 158.39.47.4
½ m Black: protonic.nyaal.npolar.no