SUTTER INSTRUMENT

Lambda VF-5 Tunable Optical Filter Changer System
External Control Quick Reference

Rev. 1.07 (20190606)

Table 1. Commands.

Byte Value			Keyboard Entry			Description			
Dec.	Hex.	Binary	Alt-keypad entry	Ctrl-char.	ASCII def./-char.	Filter Wheel Command			Special Command
						Wheel	Speed	Filter	
0	00	0000 0000	Alt-0000	^@	(NUL)	A	0	0	Move to 1st position (physical 0) at Speed 0
1	01	0000 0001	Alt-0001	^A	(SOH)			1	
2	02	0000 0010	Alt-0002	^B	(STX)			2	Move to 2nd (physical Position 2) at Speed 0
3	03	0000 0011	Alt-0003	^C	(ETX)			3	
4	04	0000 0100	Alt-0004	^D	(EOT)			4	Move to 3rd (physical Position 4) at Speed 0
5	05	0000 0101	Alt-0005	^E	(ENQ)			5	
6	06	0000 0110	Alt-0006	^F	(ACK)			6	Move to 4th (physical Position 6) at Speed 0
7	07	0000 0111	Alt-0007	^G	(BEL)			7	
8	08	0000 1000	Alt-0008	^H	(BS)			8	Move to 5th (physical Position 8) at Speed 0
9	09	0000 1001	Alt-0009	^I	(HT)			9	
10 - 15	0A - 0F	0000 1010 - 0000 1111	Alt-0010 - Alt-0015	^J - ^O	(LF) - (SI)				
16	10	0001 0000	Alt-0016	^P	(DLE)	A	1	0	Move to 1st position (physical 0) at Speed 1
17	11	0001 0001	Alt-0017	^Q	(DC1)			1	
18	12	0001 0010	Alt-0018	^R	(DC2)			2	Move to 2nd (physical Position 2) at Speed 1
19	13	0001 0011	Alt-0019	^S	(DC3)			3	
20	14	0001 0100	Alt-0020	^T	(DC4)			4	Move to 3rd (physical Position 4) at Speed 1
21	15	0001 0101	Alt-0021	^U	(NAK)			5	
22	16	0001 0110	Alt-0022	^V	(SYN)			6	Move to 4th (physical Position 6) at Speed 1
23	17	0001 0111	Alt-0023	^W	(ETB)			7	
24	18	0001 1000	Alt-0024	^X	(CAN)			8	Move to 5th (physical Position 8) at Speed 1
25	19	0001 1001	Alt-0025	^Y	(EM)			9	
26 - 31	1A - 1F	0001 1010 - 0001 1111	Alt-0026 - Alt-0031	^Z - ^_	(SUB) - (US)				
32	20	0010 0000	Alt-0032		(space)	A	2	0	Move to 1st position (physical 0) at Speed 2
33	21	0010 0001	Alt-0033		!			1	
34	22	0010 0010	Alt-0034		"			2	Move to 2nd (physical Position 2) at Speed 2
35	23	0010 0011	Alt-0035		#			3	
36	24	0010 0100	Alt-0036		$			4	Move to 3rd (physical Position 4) at Speed 2
37	25	0010 0101	Alt-0037		%			5	
38	26	0010 0110	Alt-0038		&			6	Move to 4th (physical Position 6) at Speed 2
39	27	0010 0111	Alt-0039		'			7	
40	28	0010 1000	Alt-0040		(			8	Move to 5th (physical Position 8) at Speed 2
41	29	0010 1001	Alt-0041		)			9	
42 - 47	2A - 2F	0010 1010 - 0010 1111	Alt-0042 - Alt-0047		* – /				
46	30	0011 0000	Alt-0048		0	A	3	0	Move to 1st position (physical 0) at Speed 3
49	31	0011 0001	Alt-0049		1			1	
50	32	0011 0010	Alt-0050		2			2	Move to 2nd (physical Position 2) at Speed 3

Byte Value			Keyboard Entry			Filter Wheel Command			Description
Dec.	Hex.	Binary	Alt-keypad entry	Ctrl-char.	ASCII def./-char.	Wheel	Speed	Filter	Special Command
51	33	0011 0011	Alt-0051		3			3	
52	34	0011 0100	Alt-0052		4			4	Move to 3rd (physical Position 4) at Speed 3
53	35	0011 0101	Alt-0053		5			5	
54	36	0011 0110	Alt-0054		6			6	Move to 4th (physical Position 6) at Speed 3
55	37	0011 0111	Alt-0055		7			7	
56	38	0011 1000	Alt-0056		8			8	Move to 5th (physical Position 8) at Speed 3
57	39	0011 1001	Alt-0057		9			9	
58	3A	0011 1010	Alt-0058		:				
-	-	-	–		–				
63	3F	0011 1111	Alt-0063		?				
64	40	0100 0000	Alt-0064		@			0	Move to 1st position (physical 0) at Speed 4
65	41	0100 0001	Alt-0065		A			1	
66	42	0100 0010	Alt-0066		B			2	Move to 2nd (physical Position 2) at Speed 4
67	43	0100 0011	Alt-0067		C			3	
68	44	0100 0100	Alt-0068		D	A	4	4	Move to 3rd (physical Position 4) at Speed 4
69	45	0100 0101	Alt-0069		E			5	
70	46	0100 0110	Alt-0070		F			6	Move to 4th (physical Position 6) at Speed 4
71	47	0100 0111	Alt-0071		G			7	
72	48	0100 1000	Alt-0072		H			8	Move to 5th (physical Position 8) at Speed 4
73	49	0100 1001	Alt-0073		I			9	
74	4A	0100 1010	Alt-0074		J				
-	-	-	–		–				
79	4F	0100 1111	Alt-0079		O				
80	50	0100 0000	Alt-0080		P			0	Move to 1st position (physical 0) at Speed 5
81	51	0100 0001	Alt-0081		Q			1	
82	52	0100 0010	Alt-0082		R			2	Move to 2nd (physical Position 2) at Speed 5
83	53	0100 0011	Alt-0083		S			3	
84	54	0100 0100	Alt-0084		T	A	5	4	Move to 3rd (physical Position 4) at Speed 5
85	55	0100 0101	Alt-0085		U			5	
86	56	0100 0110	Alt-0086		V			6	Move to 4th (physical Position 6) at Speed 5
87	57	0100 0111	Alt-0087		W			7	
88	58	0100 1000	Alt-0088		X			8	Move to 5th (physical Position 8) at Speed 5
89	59	0100 1001	Alt-0089		Y			9	
90	5A	0100 1010	Alt-0090		Z				
-	-	-	–		–				
95	5F	0101 1111	Alt-0095		~				
96	60	0101 0000	Alt-0096		`			0	Move to 1st position (physical 0) at Speed 6
97	61	0101 0001	Alt-0097		a			1	
98	62	0101 0010	Alt-0098		b			2	Move to 2nd (physical Position 2) at Speed 6
99	63	0101 0011	Alt-0099		c			3	
100	64	0101 0100	Alt-0100		d	A	6	4	Move to 3rd (physical Position 4) at Speed 6
101	65	0101 0101	Alt-0101		e			5	
102	66	0101 0110	Alt-0102		f			6	Move to 4th (physical Position 6) at Speed 6
103	67	0101 0111	Alt-0103		g			7	
104	68	0101 1000	Alt-0104		h			8	Move to 5th (physical Position 8) at Speed 6
105	69	0101 1001	Alt-0105		i			9	
106	6A	0101 1010	Alt-0106		j				
-	-	-	–		–				
111	6F	0101 1111	Alt-0111		o				
112	70	0111 0000	Alt-0112		p			0	Move to 1st position (physical 0) at Speed 7
113	71	0111 0001	Alt-0113		q	A	7	1	
114	72	0111 0010	Alt-0114		r			2	Move to 2nd (physical Position 2) at Speed 7

Byte Value			Keyboard Entry			Description			
						Filter Wheel Command			
Dec.	Hex.	Binary	Alt-keypad entry	Ctrl-char.	ASCII def./-char.	Wheel	Speed	Filter	Special Command
115	73	0111 0011	Alt-0115		s			3	
116	74	0111 0100	Alt-0116		t			4	Move to 3rd (physical Position 4) at Speed 7
117	75	0111 0101	Alt-0117		u			5	
118	76	0111 0110	Alt-0118		v			6	Move to 4th (physical Position 6) at Speed 7
119	77	0111 0111	Alt-0119		w			7	
120	78	0111 1000	Alt-0120		x			8	Move to 5th (physical Position 8) at Speed 7
121	79	0111 1001	Alt-0121		y			9	
122 - 203	7A - CB	0111 1010 - 1100 1011	Alt-0122 – Alt-0203						
204	CC	1100 1100	Alt-0204						**Get Status.** Returns the current filter wheel position, rotational speed, and tilt angle (microsteps).
205	CD	1100 1101	Alt-0205						
206	CE	1100 1110	Alt-0206						**Turn On Power to All Motors.**
207	CF	1100 1111	Alt-0207						**Turn Off Power to All Motors.**
208 - 217	D0 - D9	1100 0000 - 1101 1001	Alt-0208 – Alt-0217						
218	DA	1101 1010	Alt-0218						**Set Wavelength & Tilt Speed.** Followed by two bytes (low-order & high-order halves of a 16-bit integer) containing the wavelength value (338 – 800 nm). The Tilt Speed is also encoded in this command: The high-order two bits of the 16-bit wavelength integer (Bits 7 & 6 of the high-order byte) are used to encode Tilt Speeds 0 through 3.
219	DB	1101 1011	Alt-0219						**Get Current Wavelength & Tilt Speed.** Returns two bytes (lower & upper halves of a 16-bit integer) containing the wavelength value (338 – 800 nm). The Tilt Speed is encoded in the uppermost 2 bits of resulting 16-bit unsigned integer.
208 - 221	D0 - DD	1100 0000 - 11001101	Alt-0208 – Alt-0221						
222	DE	1101 1110	Alt-0222						**Set Tilt Angle.** Followed by two bytes (lower & upper halves of a 16-bit integer) containing the microsteps value (1 - 272).
223	DF	1101 1111	Alt-0223						**Batch Mode.** Allows for the sending of two commands so that the controller can execute them in quick succession. The command is followed by 4 bytes: 1 byte for the **Set Filter Wheel Position & Rotational Speed** command and 3 bytes for either the **Set Wavelength** or **Set Tilt Angle** commands.
223 - 237	DF - ED	1101 1111 - 1110 1101	Alt-0223 – Alt-0237						
238	EE	1110 1110	Alt-0238						**Set On Line Mode.** Sets the controller to online mode (opposite of Local Mode). Equivalent to pressing the ON LINE key on the keypad, except that the online state is associated with the I/O interface (Serial or USB) over which the command is sent
239	EF	1110 1111	Alt-0239						**Set Local Mode.** Sets the controller Local (offline) mode enabling the keypad for use. Equivalent to pressing the LOCAL key on the keypad.

Byte Value			Keyboard Entry			Filter Wheel Command			Description	
Dec.	Hex.	Binary	Alt-keypad entry	Ctrl-char.	ASCII def./-char.	Wheel	Speed	Filter	Special Command	
240 - 249	F0 - F9	1111 0000 - 11111 001	Alt-0240 – Alt-0249							
250	**FA**	1111 1010	Alt-0250						**TTL Control.**	A0+0x: Trigger Pulse/TTL IN disconnected.
										A3+0x: Trigger new wavelength movement on <u>Rising Edge</u>
										A4+0x: Trigger new wavelength movement on <u>Falling Edge</u>
										B0+0x: No Sync out (TTL OUT disabled)
										B1+0x: Sync out <u>high</u> for starting movement
										B2+0x: Sync out <u>low</u> for starting movement
										TTL input data even (first wavelength, end wavelength, step byte (low+high) + Direction Bit (Bit 7 (set for bidirectional; clear for one direction))
										TTL input data random (up to 80 wavelengths (160 bytes)
251	**FB**	1111 1011	Alt-0251						**Reset.** Resets the controller and all settings and positions return to factory defaults.	
252	**FC**	1111 1100	Alt-0252						**Set/Get Filter Position-to-Base Wavelength Assignment.** Used to set or get the current base wavelength that's assigned to all filter wheel positions. Each base wavelength provides the basis for which the controller uses its internal lookup table to determine which wheel position and tilt angle to use for any wavelength the user specifies with the **Set Wavelength** command.	
253	**FD**	1111 1101	Alt-0253						**Get Controller Type & Configuration** [*]	
254	**FE**	1111 1110	Alt-0254							
255	**FF**	1111 1111	Alt-0255							

NOTE 1: With the filter position movement command, all odd-numbered physical positions are not available nor are valid (physical positions 1, 3, 5, 7, and 9) when in the new wavelength switching mode. When compatibility switching mode (each of the 10 positions is assigned a wavelength allowing Lambda 10-series operation), all even and odd-numbered positions are valid.

NOTE 2: The Lambda VF-5 supports only one filter wheel (Wheel A). Therefore, Bit 7 is always set to 0.

NOTE 3: The "ASCII def./char." column for codes 128 through 255 (80 through FF hex) is left blank, since there are no ASCII character definitions for the codes in this range. However, many computers and operating systems do support characters within this range, although there is no single standard across all platforms. Furthermore, many operating systems, such as Microsoft Windows and Apple Mac OS X, have several "code pages" (character sets), many of which are country/language specific, from which the user can select. Therefore, this part of the table is left blank – if you wish, you may write in the characters defined in the character set you use on a regular basis.

Table 2. VF-5 filter wheel command structure.

Functional Bit Groups							
Byte Bit #	7	6	5	4	3	2	1	0
Group	Wheel	Rotational Speed			Filter Position			
Group Bit #	0	2	1	0	3	2	1	0
Decimal Group Values	0	0 - 7			0, 2, 4, 6, 8			
Hexadecimal Group Values	00	00 - 07			00, 02, 04, 06, 08			
Binary Group Values	0	000 - 111			0000, 0010, 0100, 0110, 1000			

NOTE: All ten positions (even and odd numbered) are valid when in Lambda 10-series compatibility mode.

Filter Wheel Byte Command Encoding: Encoding filter wheel commands into a single byte (all numbers are in decimal):

$$(rotational\ speed\ *\ 16)\ +\ position\ =\ command\ byte$$

... where *rotational speed* = 0 through 7 and *position* (even-numbered only)= 0, 2, 4, 6, or 8 (0-9 in Lambda 10-series compatibility mode). The Wheel Bit is not included in the formula because in the Lambda VF-5 it is always set to 0 (Wheel A).

Table 3. External control commands.

Command	Value (Decimal, hexadecimal, & binary)	Description
Set Filter Wheel State (move to a position at specified speed)	Wheel Select, Rotational Speed, Filter Select (Wheel Position)	Sets the filter wheel speed (0 – 7) and the filter position (0 – 9). Three items are encoded into a single byte using the following bits:
	Wheel Select (Bit 7): 0xxx-xxx (always 0)	Determines the wheel for which the command applies. Since the Lambda VF-5 supports one filter wheel, this value (encoded in Bit 7) is always 0.
	Rotational Speed: x000-xxxx – x111-xxxx (0 – 7)	Determines the rotational speed of the filter wheel. Bits 6, 5, & 4 are used to encode the value (0 – 7).
	Filter Position: xxxx-0000 (0), xxxx-0010 (2), xxxx-0100 (4), xxxx-0110 (6) xxxx-1000 (8)	Determines the position to which the wheel must rotate. The wheel supports 10 positions, of which only the even numbered positions are supported in the Lambda VF-5. The position (0, 2, 4, 6, or 8) is encoded into Bits 3, 2, 1, & 0. When in Lambda 10-series compatibility mode, all ten positions (even and odd numbered) are valid. Each of the ten positions will have been assigned a specific wavelength.
Get Status	204 CC 11001100	Returns system status in 6 bytes: 1st:.Status command echoed back 2nd: Wheel state (speed & filter position) 3rd: Shutter state (Always "Opened") 4th: Set Current Filter Angle command 5th & 6th: Angle of filter in microsteps (1 – 272)).

Command	Value (Decimal, hexadecimal, & binary)	Description
Turn Power On for All Motors *	206 CE 11001110	Instruct the controller to power on all motors.
Turn Power Off for All Motors *	207 CF 11001111	Instruct the controller to power off all motors.
Set Wavelength & Tilt Speed (move filter wheel to specified wavelength at specified tilt speed)	218 DA 11011010	Based on the wavelength (338 – 800 nm) in the next two bytes, the specific filter and tilt are set according to an internal lookup table. The speed of the tilt movement is specified in the upper two bits (Bits 7 & 6) of the high-order byte. Tilt Speeds 0, 1, 2, & 3 are permitted by encoding Bits 7 and 6 appropriately. Tilt Speed 0 is the default if no other speed is specified.
Get Current Wavelength	219 DB 11011011	Returns the current wavelength setting (in two bytes containing 338 – 800 nm), based on the current filter and angle using the internal lookup table.
Set Wheel Tilt	222 DE 11011110	The wheel's angle is set according to the number of microsteps (1 – 272) coded in the next two bytes.
Batch Mode	223 DF 11011111	The Batch command is followed by the Set Filter Wheel Speed & Position and Set Wheel Tilt commands allowing the controller to execute both commands in quick succession.
Transfer to On Line	238 EE 11101110	Puts controller on-line (serial or USB)
Transfer to Local	239 EF 11101111	Puts controller in local mode
TTL Control	250 FA 11111010	A0+0x: Trigger Pulse/TTL IN disconnected. A3+0x: Trigger new wavelength movement on <u>Rising Edge</u> A4+0x: Trigger new wavelength movement on <u>Falling Edge</u> B0+0x: No Sync out (TTL OUT disabled) B1+0x: Sync out <u>high</u> for starting movement B2+0x: Sync out <u>low</u> for starting movement TTL input data even (first wavelength, end wavelength, step byte (low+high) + Direction Bit (Bit 7 (set for bidirectional; clear for one direction)) TTL input data random (up to 80 wavelengths (160 bytes)
Reset	251 FB 11111011	Resets the controller
Set Filter Position Base Wavelength Assignment or Get Base Wavelength Assignments for	252 FC 11111100	Set if command is followed by F0 – F9 (position 0 through 9) and then two bytes containing the base wavelength in nanometers. Error Return: If an invalid filter position is specified with this command, the controller returns two bytes indicating an error. The first byte is the "error" byte, and consists of 234 decimal (EA hexadecimal). The second byte indicates the erroneous filter position and ranges from 240 (F0 hex) through 249 (F9 hex).

Command	Value (Decimal, hexadecimal, & binary)	Description
All Filter Positions		Get if command is followed by FA. The data returned begins with F0 (Filter Position 0) and two bytes containing the assigned base wavelength in nanometers, F1 and two bytes for Position 1, and so on, on to F9. The two bytes following each odd-numbered position will contain 0.
Get Controller Type and Configuration *	253 FD 11111011	Queries the controller as to its type and configuration.

Table 4. Status command return data.

Total Num. Bytes	Category	Byte Offset	Sub Category	Value (Decimal, hexadecimal, & binary)	Description
7	Command echo	0		204 CC 11001100	The Status command byte code echoed back.
	Filter wheel state	1	Wheel Select (Bit 7)	0 0 0xxxxxxx	Filter Wheel (Bit 7): Always 0.
			Speed (Bits 6, 5, & 4)	0 – 7 0 – 7 x000xxxx - x111xxxx	Speed (Bits 6, 5, & 4): 0 – 7.
			Filter Position (Bits 3, 2, 1, & 0)	0 – 9 x0 – x9 xxxx0000 - xxxx1001	Position (Bits 3, 2, 1, & 0): Even-numbered values out of 0 – 9 (0, 2, 4, 6, or 8). When in Lambda 10-series compatibility mode, all ten values (odd and even numbered) are valid.
			Error or no filter wheel installed (all bits)	10 0A 00001010	Either no filter wheel is installed or there is an error on the 15-pin wheel port.
	(Shutter state)	2	(Open)	170 AA 10101010	This Status byte should always contain the indicated value. It is present for compatibility purposes when the Lambda VF-5 is configured to be identified as a Lambda 10-B (Wheel/Shutter configuration).
	Tilt in microsteps	3	Command byte	190 BE 10111110	Command byte
		4	Lower byte of microsteps value	1 – 255 01 – FF 00000001 - 11111111	Upper and Lower bytes are combined to create a 16-bit unsigned "word" containing the

Total Num. Bytes	Category	Byte Offset	Sub Category	Value (Decimal, hexadecimal, & binary)	Description
		5	Upper byte of microsteps value	0 – 1 00 – 01 00000000 - 00000001	number of microsteps (0 through 272).
	Command return data terminator	6		13 0D 00001101	Command completion and end of data indicator (ASCII CR (Carriage Return))

Table 5. "Get Controller Type and Configuration" command return data.

Total num. bytes	Category	Byte Offset	Length	Value (Decimal, hexadecimal, & binary)	ASCII Character Sequence	Description
	Command echo back	0	1	253_{10} FD_{16} 11111101_2	ý	253 decimal; FD hexadecimal. *
	Controller type	1	4		LBVF	Lambda VF-series.
					10-B	Lambda 10-B (in Wheel/Shutter configuration) for compatibility with existing host computer control software.
14	Type of filter wheel connected	5	4		W-25	25mm, 10 position filter wheel designator used for compatibility with a Lambda 10-B in the Wheel/Shutter configuration. Of the 10 possible positions on this type of filter wheel, only 5 (all even numbered) positions are valid for a Lambda VF-5.
	Type of angle stepper connected	9	4		SVF5	SmartShutter control circuit is used for a VF-5M instead of a SmartShutter. This, combined with the "W-25" previously, specifically identifies the controller as a Lambda VF-5.
	Command return data terminator	13	1	13_{10} $0D_{16}$ 00001101_2	<CR>	ASCII CR (Carriage Return); 13 decimal, 0D hexadecimal.

*NOTE: The character shown in the "ASCII Character Sequence" column for the command echo is a typical visual representation of the byte value 253 decimal (FD hexadecimal) on both Windows and Linux platforms. However, other platforms may display a different character or nothing at all. For the command return data terminator (ASCII carriage return (13 decimal, 0D hexadecimal), generally no character will be displayed, although the carriage return is acted upon in most cases in text-based console programs.