SK5222 FlexMatrix™ Keyboard Controller

Ultra-Low Power, User-Programmable HID over I2C Keyboard Encoder with 8x20 Scan, PWM Backlight, Key Lock, Upgradable Bootloader

FEATURES

- HID over I2C v1.0 interface
- Failure-safe Bootloader for firmware upgrade
- 8 x 20 matrix keyboard scan
- 1 PWM backlight brightness control
- 4 Keyboard LEDs
- Fn, FnLock and NumLock Impacted key support
- KeyLock for undetachable washable design
- Support macro keys like “Ctrl+Alt+Del”
- 350+ predefined keys and unlimited custom key definitions
- User-Programmable keyboard matrix
- Supports all HID over I2C commands:
  - RESET
  - GET_REPORT
  - SET_REPORT
  - GET_IDLE
  - SET_IDLE
  - GET_PROTOCOL
  - SET_PROTOCOL
  - SET_POWER
- Advanced ghost key detection algorithm to maximize the key combination without additional diodes
- Built-in oscillator and digital circuit. No external crystal is needed
- QFN 46 pin package: 6.5x4.5mm 0.9 Max (LxWxH) or
- LQFP 48 pin package: 7x7mm 1.6 Max (LxWxH)
- Low power consumption: @ 3V: 0.1uA (no key pressed) 110uA (1 key) 50uA (inc per Key)
- Operation voltage range: 2.2 to 5.5V
- Industrial temperature range: -40°C to +85°C
- Custom versions available in small and large quantities

DESCRIPTION

The SK5222 is an ultra-low power (0.1uA@3V) HID over I2C interface keyboard encoder ASIC with 1 PWM backlight and 4 LEDs control. The failure-safe bootloader design allows the SK5222 to still have full keyboard functions even when any interruption failure happens during the firmware update. It’s the best choice for customized keyboard design for battery powered tablet / laptop / docking station / Instrument.

The SK5222 scans and encodes an 8-row by 20-column matrix. The key press events are translated to keyboard report. The encoder gets matrix information from on-chip matrix tables.

The SK5222 provides one key-controlled and command-controlled PWM for backlight LED PWM brightness control. An IO pin BLEN can be used to turn off the backlight circuit totally. When BLEN is used, the keyboard scan will be 8-row by 19-columns.

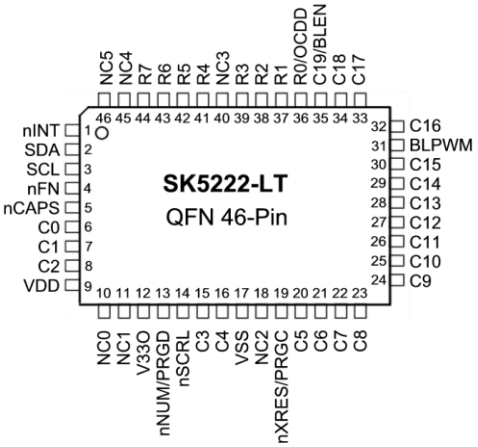
APPLICATION

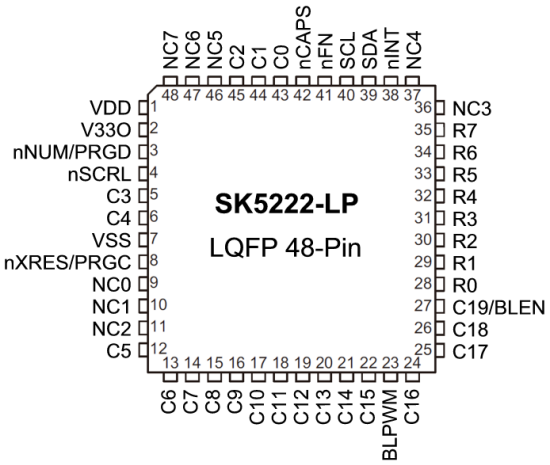
- Notebook/Netbook PCs
- Tablet PCs
- Tablet/Mobile Phone docking station
- Instruments

ORDEING INFORMATION

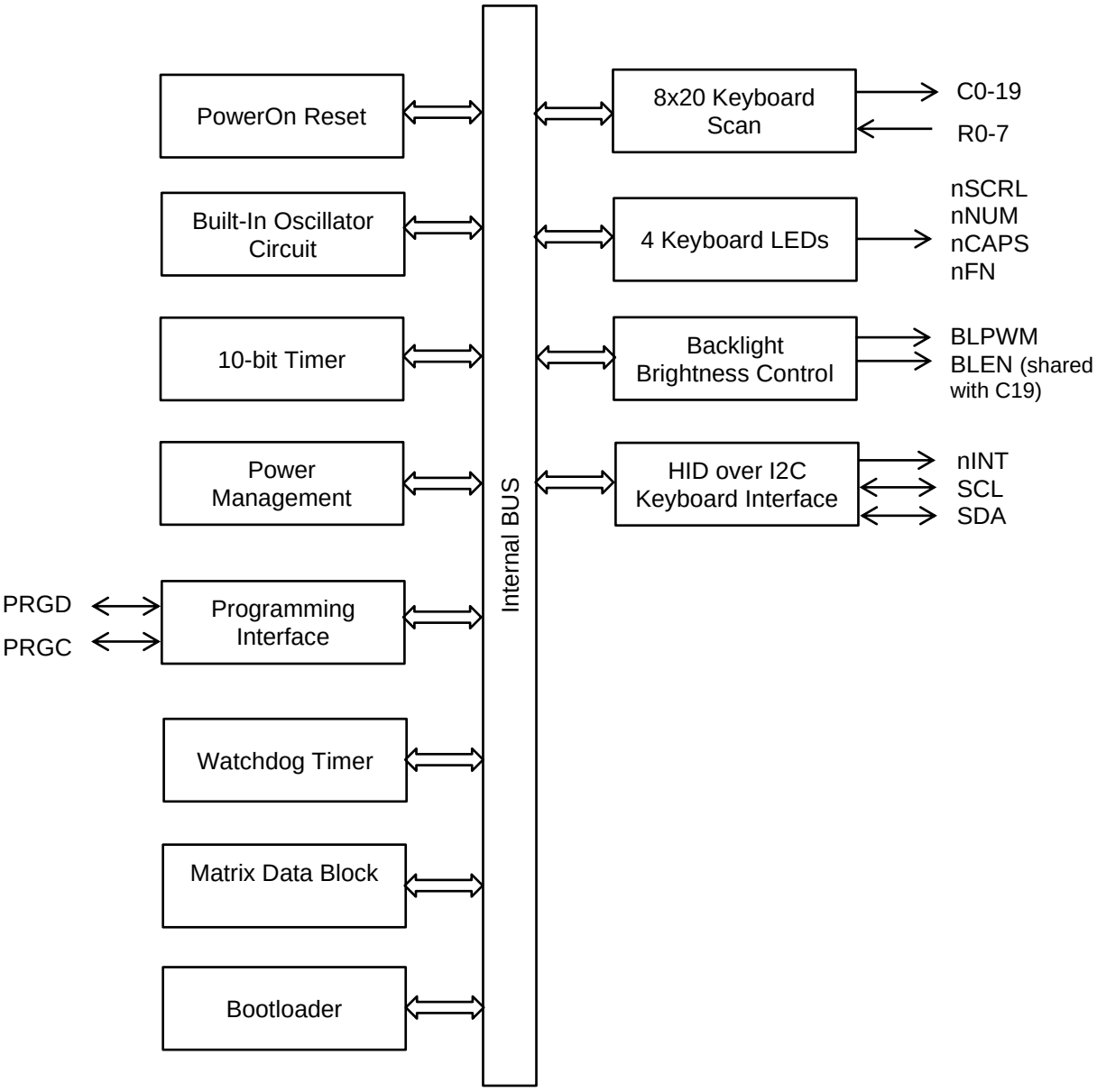
SK5222-LT QFN 46-pin, 0.4mm pitch, (6.5x4.5mm 0.9 MAX), Pb-Free, RoHS Complaint
SK5222-LP LQFP 48-pin, 0.5mm pitch, (7x7mm 1.6 MAX), Pb-Free, RoHS Complaint

PIN ASSIGNMENTS





FUNCTION BLOCK DIAGRAM



PIN DEFINITION

SK5222-LT Pin Definition

Pin No	Type	Name	Description
1	O	nINT	I2C slave interrupt line
2	IO	SDA	I2C slave data line
3	IO	SCL	I2C slave clock line
4	O	nFN	Fn lock LED
5	O	nCAPS	Caps lock LED
6 – 8	IO	C0 – C2	Column lines 0 to 2 for scan matrix
9	P	VDD	Power supply
10	NA	NC0	NC pin
11	NA	NC1	NC pin
12	P	V33O	Reserved
13	IO	nNUM/PRGD	Num lock LED / programming data line
14	O	nSCRL	Scroll lock LED
15 – 16	IO	C3 – C4	Column lines 3, 4 for scan matrix
17	P	VSS	Ground connection
18	NA	NC2	NC pin
19	I	nXRES / PRGC	External reset: low active / programming clock line
20 – 30	IO	C5 – C15	Column lines 5 to 15 for scan matrix
31	O	BLPWM	Backlight control PWM
32 – 34	IO	C16 – C18	Column lines 16 to 18 for scan matrix
35	IO	C19 / BLEN	Column line 19 for scan matrix / Backlight control LDO enable
36 – 39	I	R0 – R3	Row lines 0 to 3 for scan matrix with internal pull-up resistor
40	NA	NC3	NC pin
41 – 44	I	R4 – R7	Row lines 4 to 7 for scan matrix with internal pull-up resistor
45 – 46	NA	NC4 - NC5	NC pins

LEGEND I = Input, O = Output, IO = Input/Output, P = Power, NA = Not used

SK5222-LP Pin Definition

Pin No	Type	Name	Description
1	P	VDD	Power supply
2	P	V33O	USB 3.3 regulator output
3	IO	nNUM/PRGD	Num lock LED / programming data line
4	O	nSCRL	Scroll lock LED
5 – 6	IO	C3 – C4	Column lines 3 to 4 for scan matrix
7	P	VSS	Ground connection
8	I	nXRES/PRGC	External reset: low active / programming clock line
9-11	NA	NC0-NC2	NC pins
12 – 22	IO	C5 – C15	Column lines 5 to 15 for scan matrix
23	O	BLPWM	Backlight control PWM
24 – 26	IO	C16 – C18	Column lines 16 to 18 for scan matrix
27	IO	C19 / BLEN	Column line 19 for scan matrix / Backlight control LDO enable
28 – 35	I	R0 – R7	Row lines 0 to 7 for scan matrix with internal pull-up resistor
36 – 37	NA	NC3-NC4	NC pins
38	O	nINT	I2C slave interrupt line
39	IO	SDA	I2C slave data line
40	IO	SCL	I2C slave clock line
41	O	nFN	Fn lock LED
42	O	nCAPS	Caps lock LED
43 – 45	IO	C0 – C2	Column lines 0 to 2 for scan matrix
46 – 48	NA	NC5-NC7	NC pins

LEGEND I = Input, O = Output, IO = Input/Output, P = Power, NA = Not used

FUNCTION BLOCK DESCRIPTION

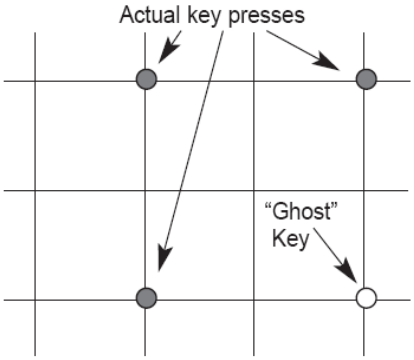
The SK5222 consists functionally of several major sections (see the block diagram on the previous page). These include power on reset, oscillator circuit, 10-bit timer, power management, programming interface, watchdog timer, keyboard scan, keyboard LEDs, backlight brightness control, matrix data block, bootloader, HID over I2C keyboard interface. All sections communicate with each other and operate concurrently.

Keyboard Scan

The SK5222 scans a keyboard organized as an 8 row by 20 column matrix for a maximum of 160 keys. Smaller size matrixes can be accommodated by leaving unused pins open. The IC provides internal pull-ups for the row input pins. When active, the encoder selects each row lines (R0-R7); for each row selected, it reads the column lines (C0-C19). A key closure is detected as a zero in the corresponding position of the matrix.

Each key found pressed is de-bounced for a period of 24ms. Once the key is verified, the corresponding key code(s) are loaded into the transmit buffer.

In any scanned contact switch matrix, whenever three keys defining a rectangle on the switch matrix are pressed at the same time, a fourth key positioned on the fourth corner of the rectangle is sensed as being pressed. This is known as the “ghost” or “phantom” key problem.



Although the problem cannot be totally eliminated without using external hardware, there are methods to neutralize its negative effects for most practical applications. Keys that are intended to be used in combinations should be placed in the same row or column of the matrix, whenever possible. Shift keys (Shift, Alt, Ctrl, Window, Fn) should not reside in the same row (or column) as any other keys. The SK5222 has built-in mechanisms to detect and reject “ghost” keys.

C19 and BLEN are shared. BLEN (backlight LDO enable) is selected at default. Therefore, the key matrix scan is 8x19 at default.

Keyboard LEDs

The SK5222 provides 4 pins to directly drive LEDs for CapsLock, NumLock, ScrollLock, Fn functions. They can be also used as general LED indicators except Fn LED. Fn LED is controlled by SK5222 automatically.

HID over I2C Interface

The SK5222 follows Microsoft’s *HID Over I2C Protocol Specification – Device Side Version 1.00* as a HID over I2C keyboard device. The SK5222 supports all HID over I2C commands:

RESET
GET_REPORT
SET_REPORT
GET_IDLE
SET_IDLE
GET_PROTOCOL
SET_PROTOCOL
SET_POWER

nINT pin can be configured to low assertion. When the SK5222 requests to send reports, it drives nINT to low and release nINT just before the report is sent.

Power Management

The SK5222 automatically enters low power modes at operation conditions. The SK5222 also support SET_POWER command to disable / enable high current peripherals like keyboard LEDs and backlights.

Under 3V operation, when no key is pressed, the SK5222 enters low power mode and only consumes 0.1uA; when one key is pressed, the SK5222 consumes only 110uA; when two or more keys are pressed, the SK5222 consumes only 50uA per extra key. The ultra-low power consumption makes it well fit battery-powered devices.

Backlight Brightness Control

The 10-bit PWM output controls the brightness of backlight circuit. The PWM clock is sourced from 6MHz clock, and the parameters such as frequency, pulse width, auto-off time are programmable.

An extra signal BLEN is automatically driven low to turn off the whole circuitry when PWM duty is 0% to minimize power consumption; while BLEN is automatically driven high when PWM duty is not 0%.

Power On Reset Circuit

The SK5222 has built-in power on reset circuit with simple external RC components.

Oscillator Circuit

The SK5222 has built-in oscillator circuit and no external crystal or resonator is needed.

10-bit Timer

The 10-bit timer provides the timing control for I2C communication, keyboard scan and sleep timer wakeup.

Programming Interface

The programming interface is reserved for Sprintek to programming new firmware. **PRGC and PRGD pins are recommended to be connected to a 6 pin header in the schematic.** The header needn't be populated in the final assembly. Three test points are preferred if 6 pin header is not allowed due to space reason.

Watchdog Timer

The SK5222 utilizes a 500ms watchdog timer to ensure robust firmware design.

Matrix Data Block

The SK5222 provides an on-chip data block to store keyboard matrix, scan code mapping table and etc. The matrix data block can be changed in the field. Custom matrix data block can be done via Sprintek custom software or customization service.

BootLoader

The SK5222 deploys a bootloader to update the newer version firmware via HID over I2C bus. The failure-safe design allows the SK5222 still have full keyboard functions even when any interruption failure happens during the firmware update.

I2C COMMAND PROTOCOL

I2C Slave Device Address

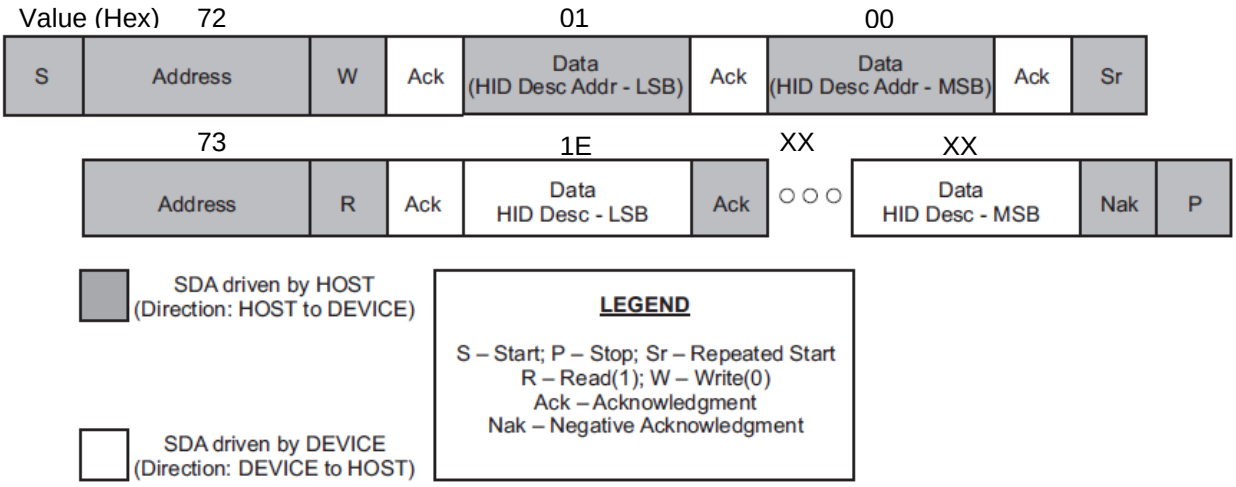
The 7-bit address of the device is shown as below 0x39. After combined with R/W bit, the 8-bit address is 0x72 for I2C write operation, 0x73 for I2C read operation.

List of Commands

The following diagram illustrates the bus communication for a data write, a data pointer write, and a data read operation. Remember that a data write operation always rewrites

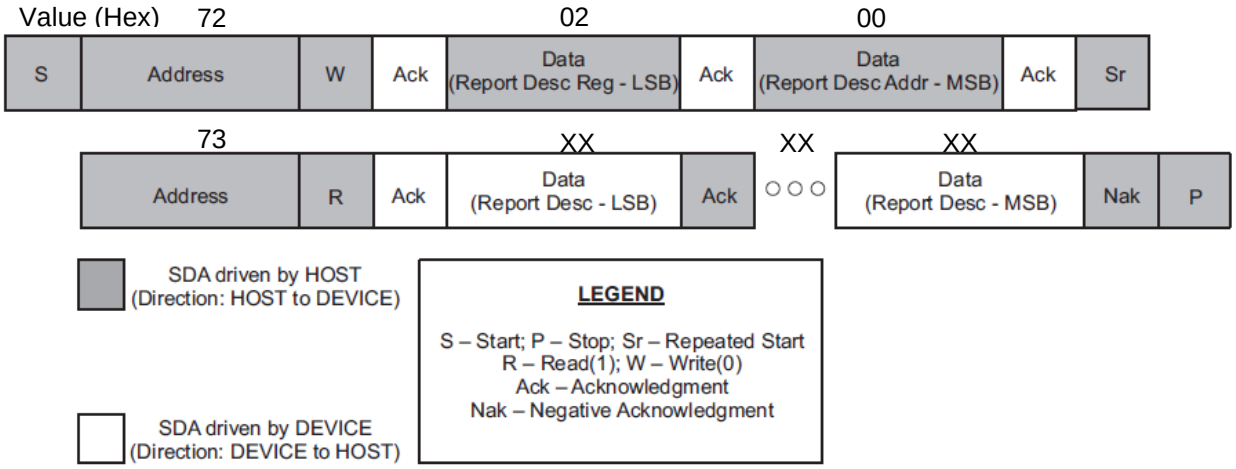
Register Address	Register Definition	R/W	Data Byte	Notes
0x0001	HID Descriptor	Read	30	
0x0002	Report Descriptor	Read	Vary	
0x0003	Input Report	Read		
0x0004	Output Report	Write		
0x0005	Command Register	Write		Support commands: RESET GET_REPORT SET_REPORT SET_POWER
0x0006	Data Register	Read/Write		

HID Descriptor Retrieval



Typical Retrieval of the HID Descriptor

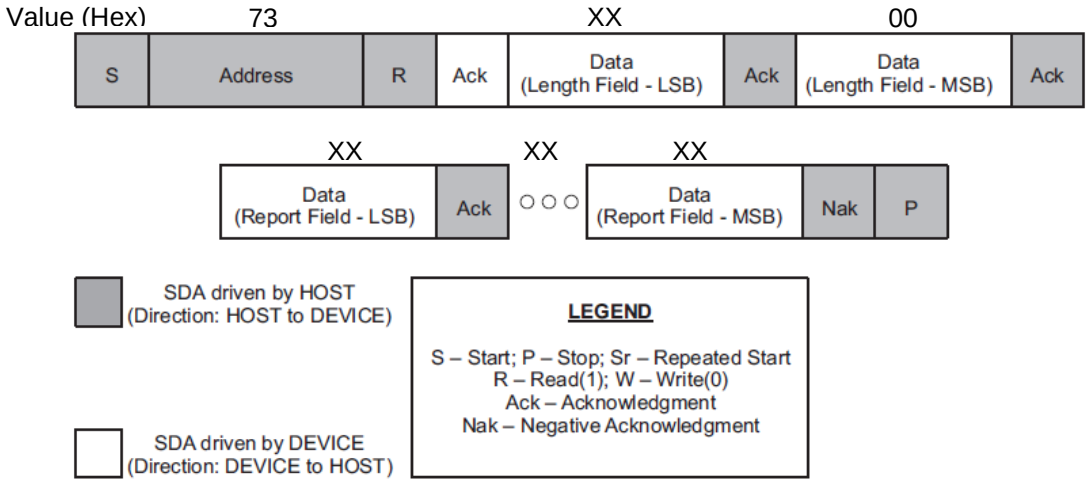
Report Descriptor Retrieval



Typical Retrieval of the Report Descriptor

The length of report descriptor is stored in HID descriptor.

Input Reports



The low byte of input report length field depends on the type of input report. Input reports are indicated by nINT assertion.

Reset Report

A reset report will be sent after the SK5222 receives powered-on-reset or after the SK5222 receives a RESET command.

Byte0	Definition	Value
0	Length Low Byte	00
1	Length High Byte	00

Keyboard Input Report (HID Page 7)

Byte0	Definition	Value
0	Length Low Byte	0B
1	Length High Byte	00

2	Report ID	01
3	Modifier Keys **Bit7** **Bit6** **Bit5** **Bit4** **Bit3** **Bit2** **Bit1** **Bit0** RightGUI RightAlt RightShift RightCtrl LeftGUI LeftAlt LeftShift LeftCtrl	XX
4	Reserved	00
5	Key1 UsageID	XX
6	Key2 UsageID	XX
7	Key3 UsageID	XX
8	Key4 UsageID	XX
9	Key5 UsageID	XX
10	Key6 UsageID	XX

System ACPI Input Report (HID Page 1)

Byte0	Definition	Value
0	Length Low Byte	04
1	Length High Byte	00
2	Report ID	02
3	System Key Bit Definition **Bit7** **Bit6** **Bit5** **Bit4** **Bit3** **Bit2** **Bit1** **Bit0** 0 0 0 0 0 Wake Up Sleep Power Down	XX

Consumer Key Input Report (HID Page C)

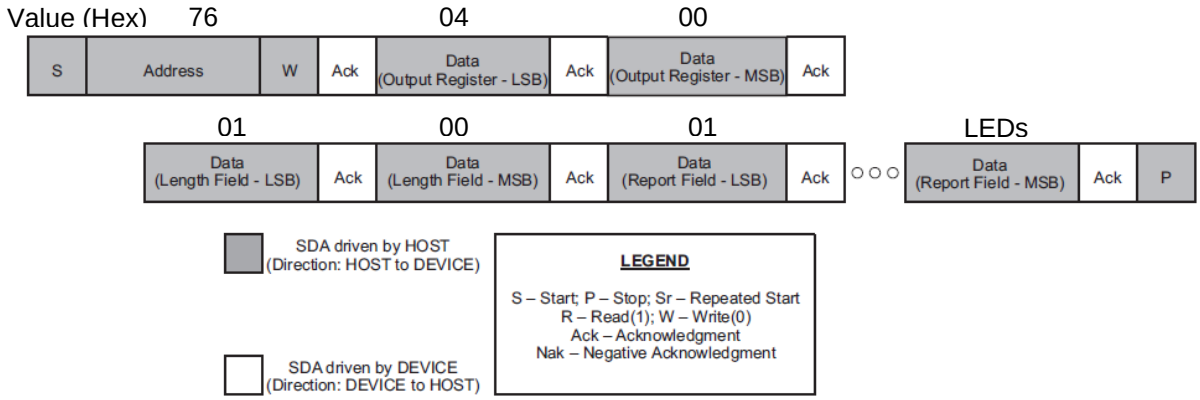
Byte0	Definition	Value
0	Length Low Byte	07
1	Length High Byte	00
2	Report ID	03
3	Consumer Key Bit Definition Byte 0 **Bit7** **Bit6** **Bit5** **Bit4** **Bit3** **Bit2** **Bit1** **Bit0**	XX
4	Consumer Key Bit Definition Byte 1 **Bit7** **Bit6** **Bit5** **Bit4** **Bit3** **Bit2** **Bit1** **Bit0**	XX
5	Consumer Key Bit Definition Byte 2 **Bit7** **Bit6** **Bit5** **Bit4** **Bit3** **Bit2** **Bit1** **Bit0**	XX
6	Consumer Key Bit Definition Byte 3 **Bit7** **Bit6** **Bit5** **Bit4** **Bit3** **Bit2** **Bit1** **Bit0**	XX

Note: The key definition is described in HID report descriptor.

User Key Input Report (HID Page FF00)

Byte0	Definition	Value
0	Length Low Byte	05
1	Length High Byte	00
2	Report ID	04
3	Vendor Key Bit Definition Byte 0 **Bit7** **Bit6** **Bit5** **Bit4** **Bit3** **Bit2** **Bit1** **Bit0** User7 User6 User5 User4 User3 User2 User1 User0	XX
4	Vendor Key Bit Definition Byte 0 **Bit7** **Bit6** **Bit5** **Bit4** **Bit3** **Bit2** **Bit1** **Bit0** UserF UserE UserD UserC UserB UserA User9 User8	XX

Output Reports



Set Keyboard LEDs

Byte0	Definition								Value
0	Length Low Byte								04
1	Length High Byte								00
2	Report ID								01
3	LED Bit Definition								XX
	Bit7	**Bit6**	**Bit5**	**Bit4**	**Bit3**	**Bit2**	**Bit1**	**Bit0**	
	0	0	0	0	0	Scroll Lock - LED2	Caps Lock - LED1	Num Lock - LED0	

Fn LED is controlled by SK5222 automatically.

Command and Data Register

The HID over I2C spec requires that all devices respond to certain commands. The commands are issued to the command register. The command is an opcode as defined by the HID over I2C spec. The operand for the command goes to the data register. Below is a list of commands supported by the SK5222.

Op Code	Command Name	Effective on Device
0001b	RESET	Device is reset and all registers are returned to default value. This command has the same effect on the device as a power on reset.
0010b	GET_REPORT	Get current key states specified by report ID and transferred to Data Register
0011b	SET_REPORT	Data register contents are used to turn on/off LED.
0100b	GET_IDLE	Get key repeat rate in ms. 500ms at default.
0101b	SET_IDLE	Set key repeat rate in ms.
0110b	GET_PROTOCOL	Get current protocol. 0=boot protocol; 1=report protocol (default).
0111b	SET_PROTOCOL	Set protocol to either boot or report.
1000b	SET_POWER	All LEDs are turned off, and device is in lowest current mode (will still detect key presses) when power mode is in SLEEP (value 1).

KEYBOARD MATRIX DESIGN

Keyboard Matrix

The SK5222 supports 8X20 keyboard matrix table. It supports Fn, FnLock, NumLock impacted key definitions, macro key definition and function key definition. Customers can map any key to any key matrix location. 350+ predefined keys are provided, and user-customized keys are supported.

Design Keyboard Matrix

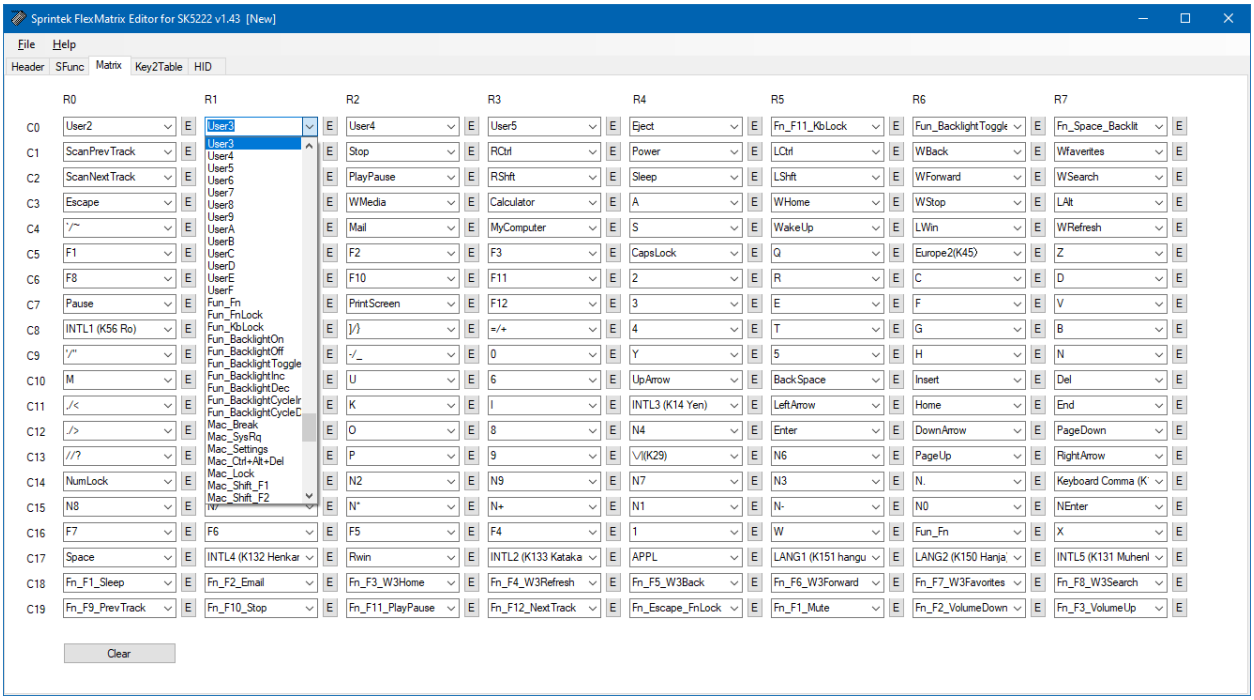
Please refer to Microsoft Windows Platform Design Notes “Keyboard Scan Code Specification” to get more information.

Create Keyboard Matrix

The FlexMatrix Editor program enables the user to create keyboard matrix including macro key definition and function key definition, then save them in binary format.

The Editor program allows the user to assign a logical key to any position in the 8 x 20 matrix. Once a matrix has been created, it is saved in a binary file. The file can be downloaded to the SK5222 flash data block via FlexMatrix Programmer software.

The Editor program can be downloaded from http://sprintek.com/support/Downloads.aspx. Here is the screen snapshot of FlexMatrix Editor software.

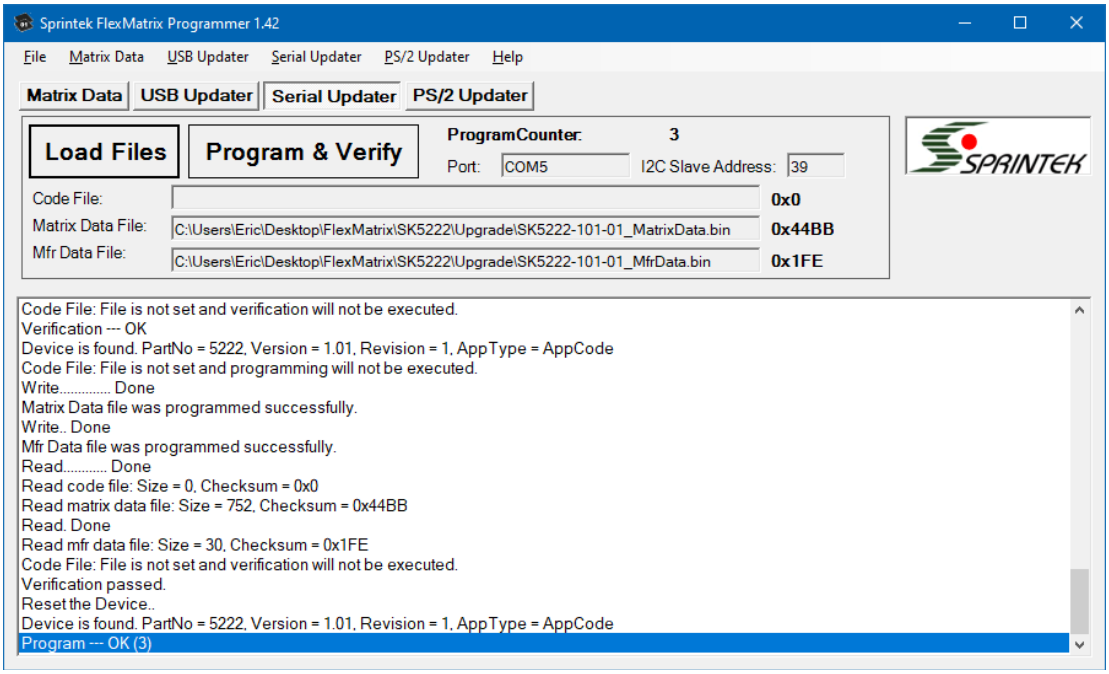


Screen snapshot of FlexMatrix™ Editor

Download Keyboard Matrix

The FlexMatrix Programmer program enables the user to download matrix binary file to the SK5222, upload matrix data from the SK5222’s flash data block to a binary file.

The Programmer program can be downloaded from http://sprintek.com/support/Downloads.aspx. Here is the screen snapshot of FlexMatrix Programmer software.

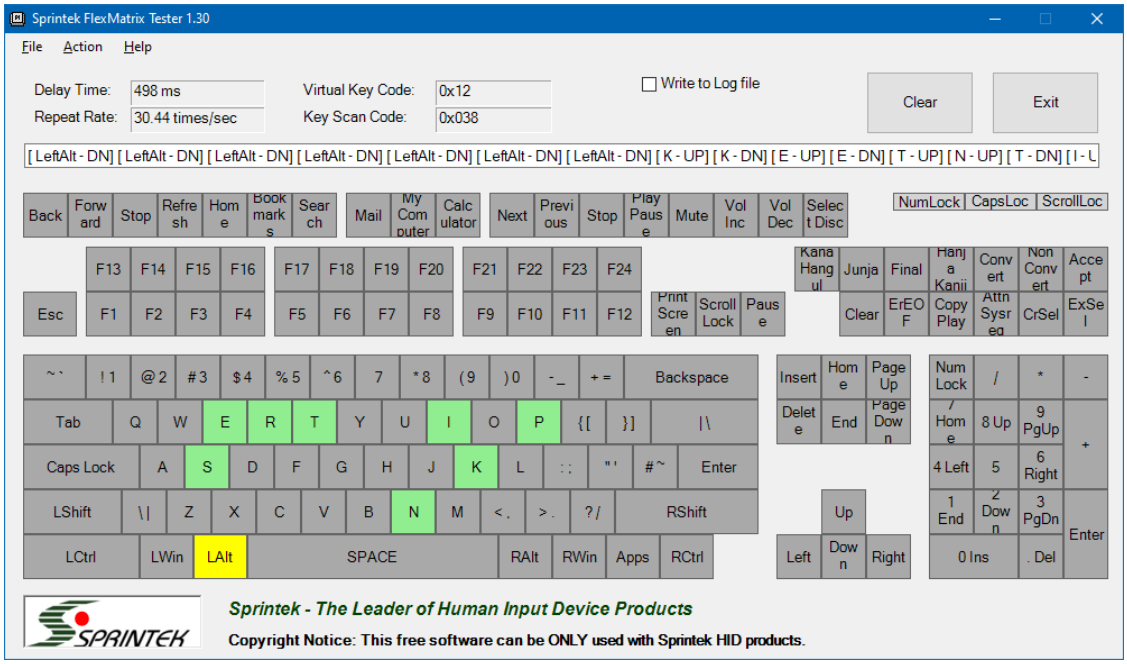


Screen snapshot of FlexMatrix™ Programmer – Matrix Data Upgrade

Test Keyboard Matrix

Sprintek offers a keyboard test tool to verify your keyboard design.

The Tester program can be downloaded from http://sprintek.com/support/Downloads.aspx. Here is the screen snapshot of FlexMatrix Programmer software.

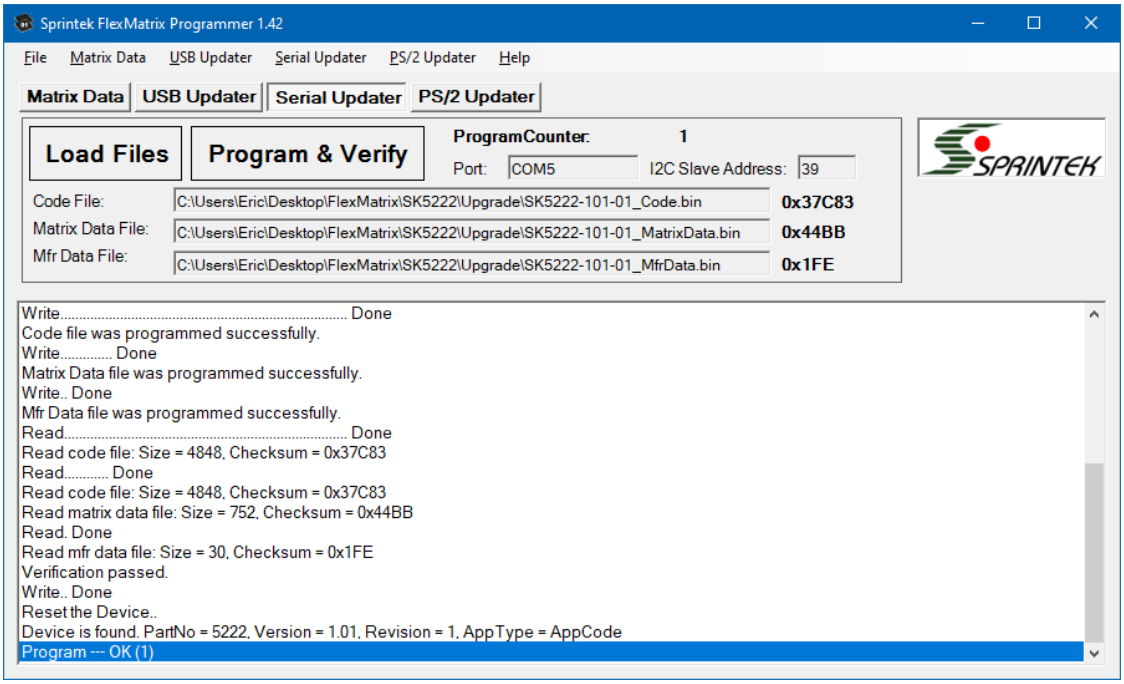


Screen snapshot of FlexMatrix™ Tester

Code Upgrade

The SK5222's bootloader to support field code upgrade. The feature enables users to enjoy new features of your design. 3 files can be upgraded via the FlexMatrix Programmer program: code file, matrix data, manufacturer data.

The Tester program can be downloaded from http://sprintek.com/support/Downloads.aspx. Here is the screen snapshot of FlexMatrix Programmer software.



Screen snapshot of FlexMatrix™ Programmer – Code Upgrade

DEFAULT KEYBOARD MATRIX

The following table shows the default keyboard matrix on chip. Please fill out this table and send it to Sprintek for customized design.

	R0	R1	R2	R3	R4	R5	R6	R7
C0	User2	User3	User4	User5	Eject	F11_ KbLock	Backlit Toggle	Space_Bac klitToggle
C1	PrevTrack	VolUp	Stop	Ctrl-R	Power	Ctrl-L	WBack	WFavorites
C2	NextTrack	VolDn	Play/Pause	Shift-R	Sleep	Shift-L	WForward	WSearch
C3	Esc	Alt-R	Media	Calculator	A	WHome	WStop	Alt-L
C4	~`	Mute	Email	MyComp	S	Wake Up	Win-L	WRefresh
C5	F1	Tab	F2	F3	Caps Lock	Q	K45 UK|	Z
C6	F8	F9	F10	F11	@2	R	C	D
C7	Pause	Scroll Lock	PrtSc	F12	#3	E	F	V
C8	K56 JP-Ro	K42 UK#~	}]	+=	$4	T	G	B
C9	“’	{[	_-	)0 /	Y	%5	H	N

C10	M	J	U	^6	↑	Back Space	Insert	Delete
C11	<,	&7	K	I	K14 JP-Yen	←	Home	End
C12	>.	L	O	*8	N4	Enter	↓	PgDn
C13	?/	:; —	P	(9	K29 |	N6	PgUp	→
C14	Num Lock	N5	N2	N9	N7	N3	N.	K107 BR
C15	N8	N/	N*	N+	N1	N-	N0	NEnter
C16	F7	F6	F5	F4	!1	W	**Fn**	X
C17	Space	K132 JP-M	**Win-R**	K133 JP-R	Apps	K151 KR-R	K150 KR-L	K131 JP-L
C18	F1_Sleep	F2_Email	F3_WHome	F4_ WRefresh	F5_ WBack	F6_ WForward	F7_ WFavorites	F8_ W3Search
C19	F9_ PrevTrack	F10_Stop	F11_ Play/Pause	F12_ NextTrack	Escape_ FnLock	F1_Mute	F2_ VolDn	F3_ VolUp

HID USAGE TABLE

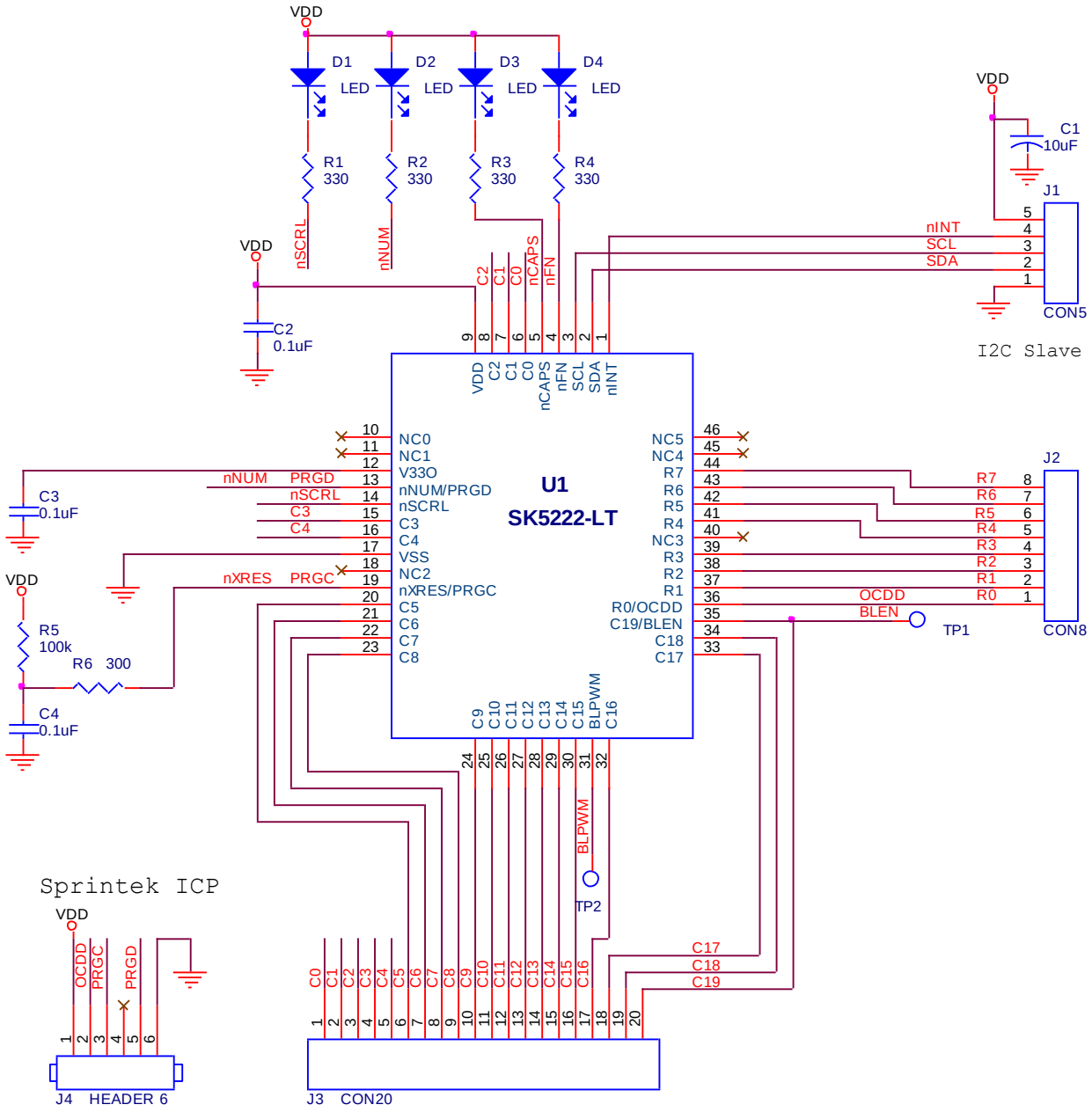
Here lists special keys' HID usage code. All other keys are normal keys listed in usage page 7 in document "HID Usage Tables 1.2" from https://usb.org/.

Key	Usage Page	Usage
Power	01	81
Sleep	01	82
Wake Up	01	83
NextTrack	0C	B5
PrevTrack	0C	B6
Stop	0C	B7
Eject	0C	B8
Play/Pause	0C	CD
Mute	0C	E2
VolUp	0C	E9
VolDn	0C	EA
Media	0C	183
Email	0C	18A
Calculator	0C	192
My Computer	0C	194
WSearch	0C	221
WHome	0C	223
WBack	0C	224
WForward	0C	225
WStop	0C	226
WRefresh	0C	227
WFavorites	0C	22A
K14	07	89
K29	07	31
K42	07	32
K45	07	64
K56	07	87
K107	07	85

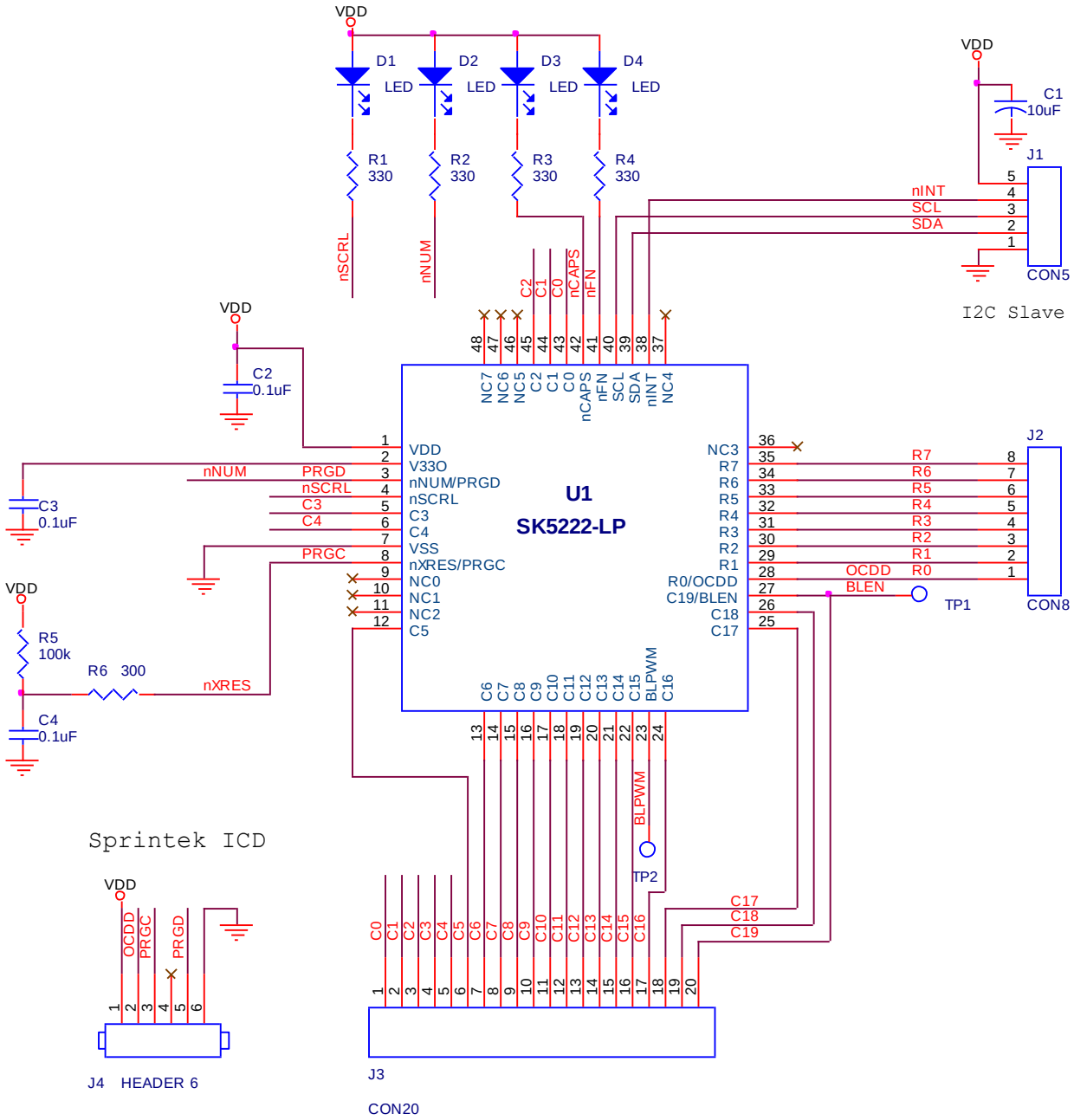
Key	Usage Page	Usage
K131	07	8B
K132	07	8A
K133	07	88
K150	07	91
K151	07	90
User0	FF00	EF
User1	FF00	F0
User2	FF00	F1
User3	FF00	F2
User4	FF00	F3
User5	FF00	F4
User6	FF00	F5
User7	FF00	F6
User8	FF00	F7
User9	FF00	F8
UserA	FF00	F9
UserB	FF00	FA
UserC	FF00	FB
UserD	FF00	FC
UserE	FF00	FD
UserF	FF00	FE

SCHEMATIC OF REFERENCE DESIGN

SK5222-LT Schematic



SK5222-LP Schematic



ELECTRONICS SPECIFICATIOIN

Absolute Maximum Ratings

Symbol	Description	Min	Typ	Max	Units	Notes
TSTG	Storage Temperature	-50	25	+125	ºC	
VDD	Supply Voltage on Relative to VSS	-0.3	-	+6.0	V	
VIO	DC Input Voltage	VSS-0.3	-	VDD+0.3	V	
IMTO	Maximum Current into all pins in total	-100	-	+150	mA	

Operating Temperature

Symbol	Description	Min	Typ	Max	Units	Notes
TOP	Operating Temperature	-40	-	+85	ºC	

DC Electrical Characteristics

Symbol	Description	Min	Typ	Max	Units	Notes
VDD	Supply Voltage at USB regulator enabled interface	2.2	-	5.5	V	
IDD	Supply Current when no key is pressed		0.3	2	uA	5V
			0.1	1	uA	3V
IDDK	Supply Current when one key is pressed		260		uA	5V
			110		uA	3V
IDDE	Incremental Supply Current when one more key is pressed		115		uA	5V
			50		uA	3V
LVR	Low voltage reset	1.995	2.1	2.205	V	
RPU	Pull-up Resistor	10	30	50	kΩ	5V
		20	60	100	kΩ	3V

GPIO Electrical Characteristics

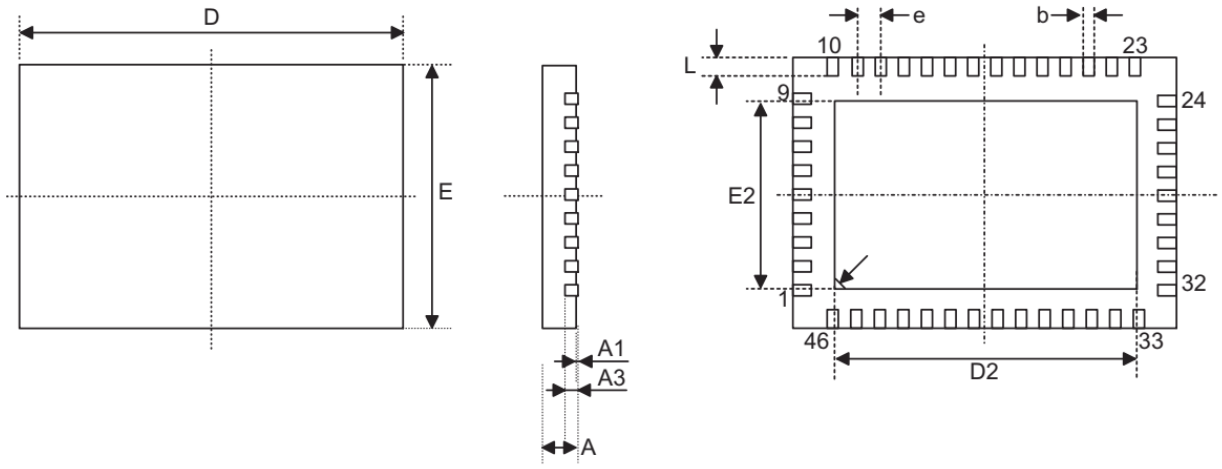
Symbol	Description	Min	Typ	Max	Units	Notes
VIL	Input Low Level	-	-	0.2VDD	V	
VIH	Input High Level	0.8VDD	-	-	V	
BLFPWM	Backlight PWM frequency	91.5	366	46,875	Hz	366Hz is default.

I2C Slave Electrical Characteristics

Symbol	Description	Min	Typ	Max	Units	Notes
BI2C	I2C baud rate	-	-	400k	Hz	

PACKAGING INFORMATION

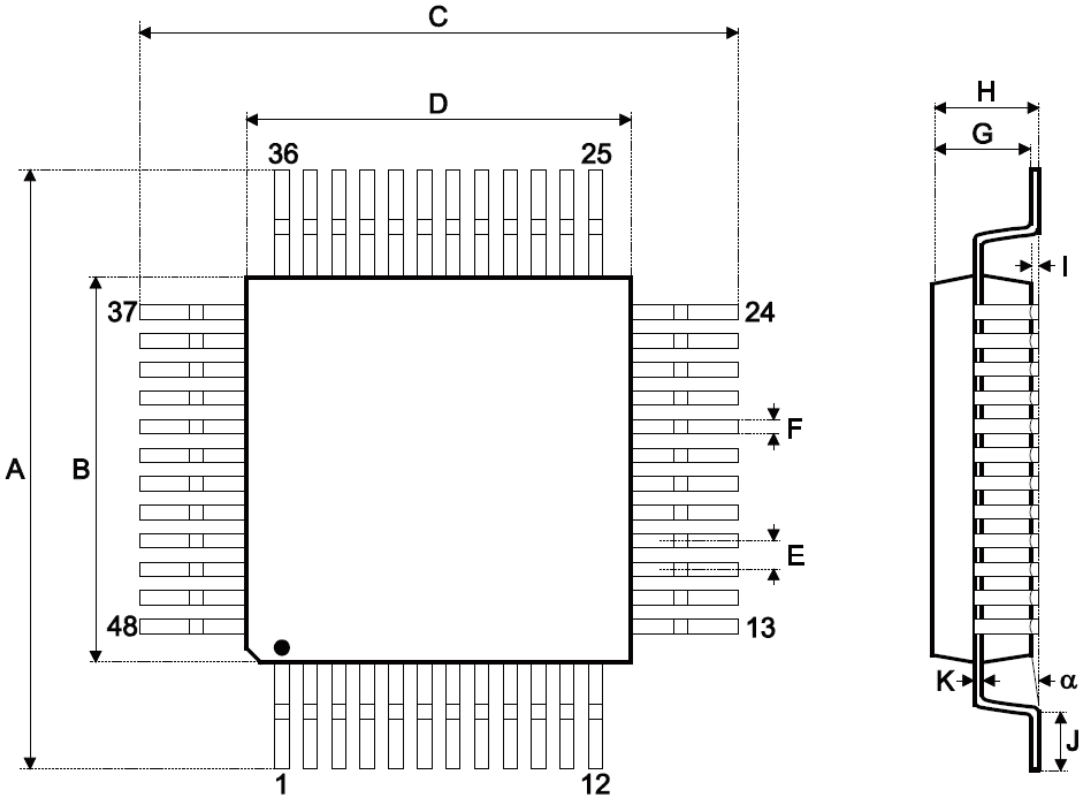
SK5222-LT Drawing



Symbol	Dimensions in mm		
	Min.	Nom.	Max.
A	0.8	0.85	0.9
A1	0	0.02	0.04
A3	-	0.2 ref	-
b	0.15	0.2	0.25
D	6.45	6.5	6.55
E	4.45	4.5	4.55
e	-	0.4 BSC.	-
D2	5	5.1	5.2
E2	3	3.1	3.2
L	0.3	0.4	0.5

SK5222-LT 46-pin (6.5x4.5mm 0.9 MAX) SAW Type QFN

SK5222-LP Drawing



Symbol	Dimensions in mm		
	Min.	Nom.	Max.
A	-	9.00BSC	-
B	-	7.00BSC	-
C	-	9.00BSC	-
D	-	7.00BSC	-
E	-	0.50BSC	-
F	0.17	0.22	0.27
G	1.35	1.40	1.45
H	-	-	1.60
I	0.05	-	0.15
J	0.45	0.60	0.75
K	0.09	-	0.20
α	0 °	-	7 °

SK5222-LP 48-pin (7x7mm 1.6 MAX) LQFP

SALE AND SERVICE INFORMATION

To obtain information about Sprintek Corporation or FlexMatrix keyboard controller family sales and technical support, reference the following information.

Sprintek Corporation
4969 Corral St.
Simi Valley, CA 93063, USA
Web Site: http://www.sprintek.com

REVISION HISTORY

Revision	Issue Date	Description
1.00	August 12, 2020	Initial release