UM1698
User manual

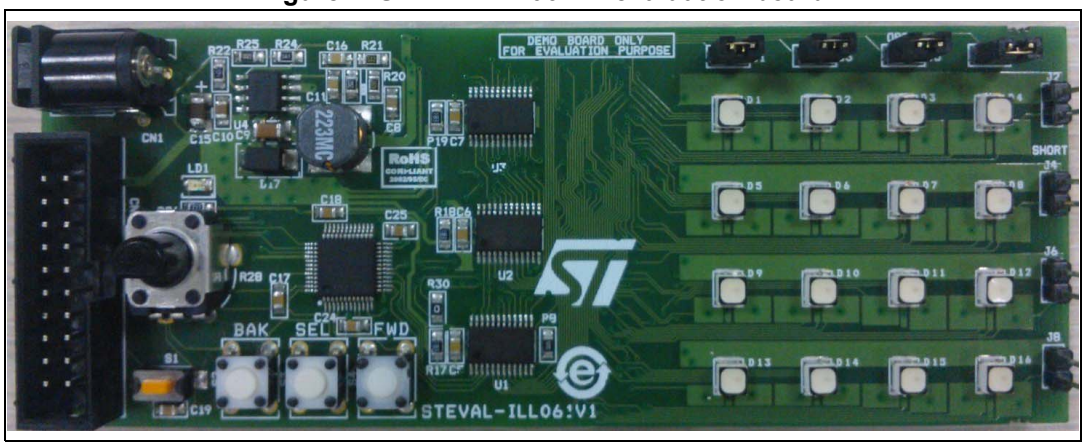
STEVAL-ILL061V1: high brightness RGB LED array driver with local dimming and diagnostics based on LED1642GW and STM32

Introduction

This user manual describes features of the STEVAL-ILL061V1 evaluation board from STMicroelectronics. The board is based on the LED1642GW independent PWM LED driver controlled through an STM32 microcontroller SPI interface. An L7981 DC-DC converter provides the voltages and power for overall functioning of the board.

This manual explains how to use the board, including a description of the hardware setup, demonstration firmware functions, interconnection with a PC, graphical user interface to demonstrate the driver features, and how to evaluate of the LED1642GW device.

Figure 1. STEVAL-ILL061V1 evaluation board



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1 Getting started

1.1 Package contents

The STEVAL-ILL061V1 constant-current LED driver LED1642GW-based evaluation board consists of:

- Hardware: one evaluation board
- Software: graphical user interface
- Document: user manual

1.2 Hardware description

The STEVAL-ILL061V1 evaluation board has an on-board DC input power supply, 32-bit microcontroller, JTAG-SWD connector to program the microcontroller, 16 RGB LEDs and buttons to control the driver, three LED1642GW LED drivers (one for each channel, viz. red, green and blue as shown in the block diagram in *Figure 4*).

Figure 2. Setup of the board (top)

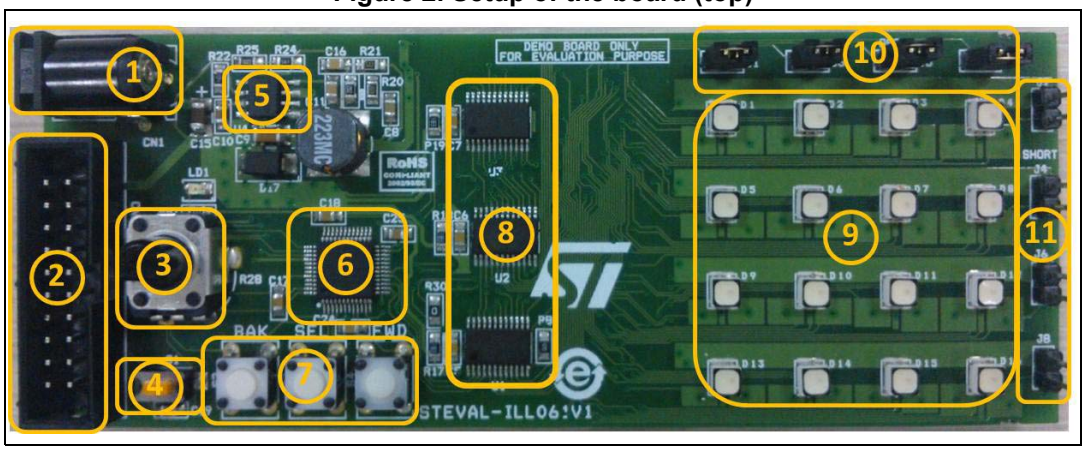
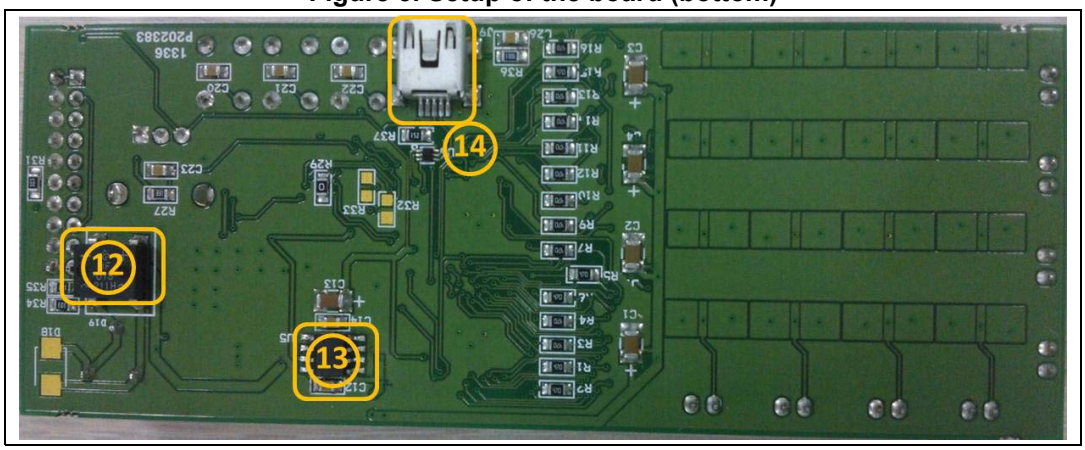


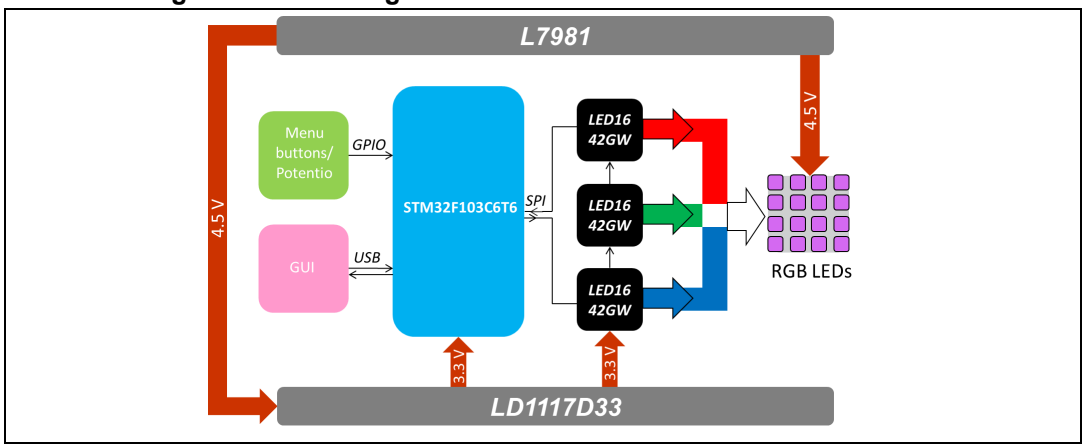
Figure 3. Setup of the board (bottom)



1. 6 - 28 V DC power supply with polarity and overvoltage protection, standard DC jack input
2. JTAG/SWD connector to program the microcontroller
3. Potentiometer/knob
4. Back/Reset switches
5. L7981: high efficiency switching regulator
6. STM32F103C6T6 microcontroller
7. Menu buttons
8. LED1642GW (TSSOP24 - exposed pad) LED driver
9. 16 RGB (PLCC - 4) LEDs
10. 4 jumpers to simulate open-circuit error
11. 4 jumpers to simulate short-circuit error
12. Diode bridge
13. LD1117: 3.3 volts linear voltage regulator
14. Mini-B type female USB connector

1.3 Block diagram of the STEVAL-ILL061V1 evaluation board

Figure 4. Block diagram of STEVAL-ILL061V1 evaluation board



1.4 Modes of operation

The evaluation board has two modes of operation:

- Stand-alone mode: In this mode, the board is controlled via on-board push buttons and potentiometer
- GUI mode: If connected to a PC, the board is in GUI mode and it has control of board

2 Board function overview

2.1 Board controls

2.1.1 Power supply

The board is powered by 6 to 28 V DC. The power source must be able to deliver sufficient current depending on the input voltage. Since the board has a built-in diode bridge, the polarity of the input voltage is not specified.

2.1.2 Microcontroller JTAG

The board is equipped with a standard 20-pin JTAG connector allowing debugging and development of the STM32 microcontroller firmware.

2.1.3 Microcontroller clock, reset, USB clock

The STM32 on-board microcontroller uses its internal RC oscillator to generate an 8 MHz clock (which is converted to 48 MHz by a PLL). The clock is also used to drive the USB. Since the internal RC oscillator does not allow the achievement of the clock stability defined in the USB specifications, it is recommended not to use the internal RC oscillator in conjunction with the USB interface. The USB is used only for demonstration purposes, but the performance is limited due to this internal RC oscillator stability.

2.1.4 Jumpers for LED failure simulation

LED defects can be simulated by using J1 to J8 jumpers:

- Removing a jumper on J1, J3, J5 and J7 causes green LED open-circuit error in D1, D2, D3 and D4, respectively (detailed in *Section 3.4*).
- Placing a jumper on J2, J4, J6 and J8 causes red LED short-circuit error in D4, D8, D12 and D16, respectively (detailed in *Section 3.4*).

These simulated defects can be detected during the activation of the error detection mode (see 4.4 Mode “d”- error detection demo). The defective LED is highlighted by switching on the corresponding blue LED in stand-alone mode and by flashing the corresponding circle in the LED map in GUI mode.

2.2 Board features

2.2.1 Features of the evaluation board in stand-alone mode

- Demonstrates pre-configured patterns (with adjustable brightness/speed) such as random color, wave effect with smooth gradual transition and solid color demo with abrupt transition between the frames
- On-board buttons to switch between the demos
- Potentiometer as a slider to control speed or brightness of the pattern
- Open-circuit, short-circuit and combined error detection simulation using open-circuit/short-circuit jumpers

2.2.2 Features of the evaluation board in GUI mode

- All the features present in stand-alone mode can be controlled using the GUI
- Global brightness control to change the brightness of all the channels
- 4 Individual channel brightness control to control individual brightness of each LED
- Reference PWCLK control from 500 KHz to 24 MHz
- Frame programming mode and 4 predefined presets with variable transition time between frames
- Open, short and combined error detection selection and representation on GUI
- Error detection in “no loop” and in loop of 0.5 s and 1 s
- Reading/Writing configuration register

2.3 Key devices on the evaluation board

The following are the major devices responsible for the board's functionality:

L7981: The L7981 is a high efficiency step-down 250 kHz switching regulator with up to 3 A current to the load. Input voltage varies from 4.5 to 28 V and also depends on the required output. It supports low dropout operation along with zero load current operation. Overcurrent and thermal protection are provided for safe operation of the device. On the board L7981 powers LD1117 and RGB LEDs.

LD1117D33: The LD1117D33 is a fixed 3.3 V output, low drop voltage regulator able to provide up to 800 mA. It powers the microcontroller and LED drivers.

STM32F103x: The STM32F103x is a 32-bit RISC microcontroller based on the ARM Cortex M3 core. It has advance APB bus, ADC, Timer, I^2C, SPI, USART and USB peripherals.

Diode bridge: The diode bridge at the input of power supply ensures the satisfactory operation of the board irrespective of the input voltage polarity.

RGB LED: 16 high performance tricolor (red, green & blue) SMD LEDs with wide viewing angle and high brightness are mounted in 4x4 fashion on the board. The features shown in *Table 1* make these LEDs suitable for video signage.

Table 1. SMD tricolor LED features

Channel	Dominant wavelength	Luminous intensity	Viewing angle
Red	619-624 nm	450-1120 mcd	120°
Green	520-540 nm	900-2240 mcd	
Blue	460-480 nm	224-560 mcd	

3 Stand-alone mode

The STEVAL-ILL061V1 evaluation board runs in stand-alone mode when not connected to a PC. The main features of stand-alone mode are:

- Brightness control for each LED in preconfigured patterns
- Speed and brightness control of the patterns
- Open error, short error and combined error detection to detect LED failure

After DC input is fetched, it starts with brief animation on 4x4 RGB LED matrix followed by informing USB connectivity. If USB is connected, it displays “U” in green or otherwise “!U” in red.

Figure 5. USB connected

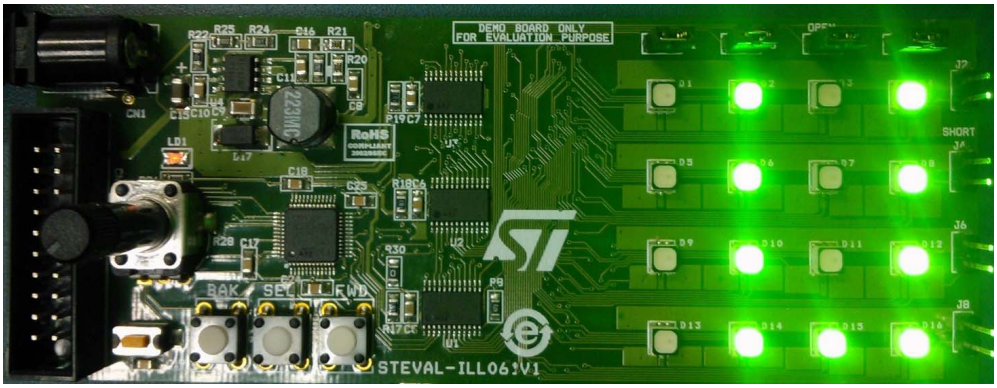
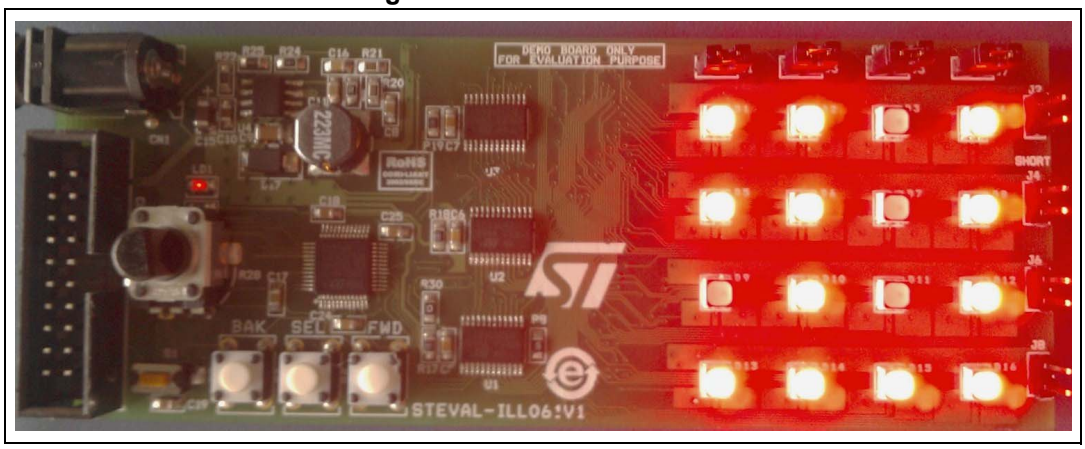


Figure 6. USB not connected



The RGB LEDs are switched on to display letters 'a', 'b', 'c' or 'd'. Each letter represents a menu option (or mode). An action on the menu buttons (BAK, SEL, FWD) allow to select the required mode and display another letter.

Figure 7. Mode “a” selected

Figure 8. Mode “b” selected

Figure 9. Mode “c” selected

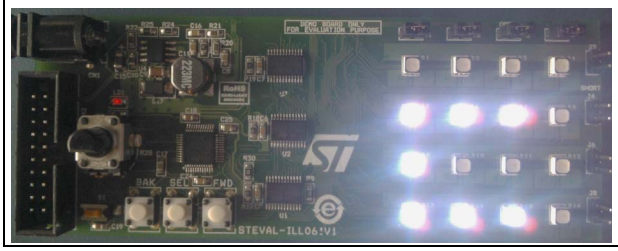


Figure 10. Mode “d” selected

The firmware mode menu items are as follows:

- Mode “a” random color demonstration
- Mode “b” wave color demonstration
- Mode “c” solid color demonstration
- Mode “d” error detection demonstration

The board can be controlled by four buttons and one knob (no. 3,4 & 7, shown in *Chapter 1.2*):

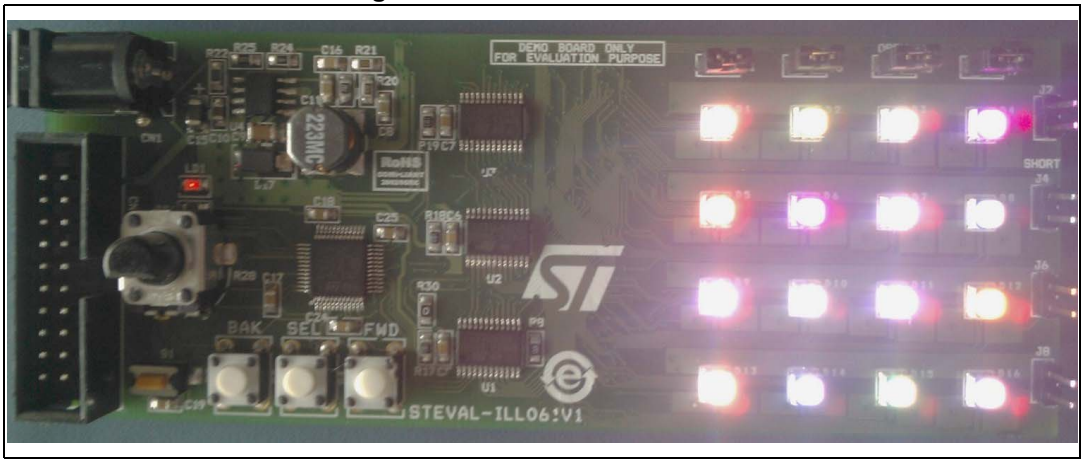
- Button Reset - exit from current task in to the main menu (resets the microcontroller)
- Button BAK - select the previous mode
- Button SEL - enter the chosen mode in menu
- Button FWD - select the next mode
- Knob - changes the brightness or speed of the selected pattern

Different modes are described in the sections below. For transition between the modes, refer to *Figure 15*.

3.1 Mode “a”- random color demo

Random color patterns (mix of RGB) are generated and shown in a 4x4 matrix display.

Figure 11. Random color demo



3.1.1 Random color speed (RCS)

This mode demonstrates a random color pattern with gradual transition between the frames with adjustable speed using a knob. Rotating the knob clockwise increases transition speed, and vice-versa. Brightness levels for all the channels are fixed.

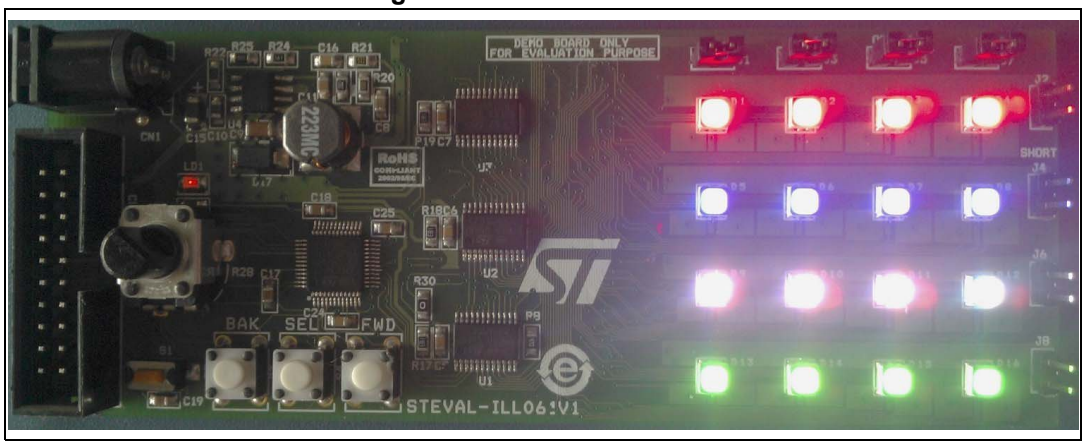
3.1.2 Random color brightness (RCB)

This mode demonstrates a random color pattern with gradual transition between the frames with adjustable brightness using a knob. Rotating the knob clockwise increases brightness, and vice-versa. Transition speed is fixed.

3.2 Mode “b”- wave color demo

Each red, green, blue and white color is displayed in each line and successively interchange with each other in sequence to demonstrate a wave effect.

Figure 12. Wave color demo



3.2.1 Wave color speed (WCS)

This mode demonstrates a wave effect with gradual transition between the frames with adjustable speed using a knob. Rotating the knob clockwise increases transition speed, and vice-versa. Brightness levels for all the channels are fixed.

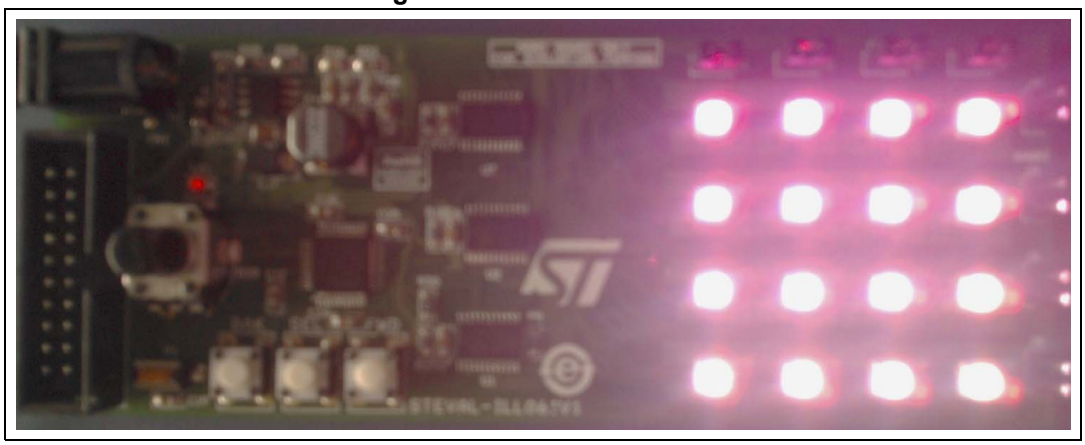
3.2.2 Wave color brightness (WCB)

This mode demonstrates a wave effect with gradual transition between the frames with adjustable brightness using a knob. Rotating the knob clockwise increases brightness, and vice-versa. Transition speed is fixed.

3.3 Mode “c”- Solid color demo

This mode demonstrated red, green, blue, brown, purple, blue-green and white color in a sequential loop on the LED map.

Figure 13. Solid color demo



3.3.1 Solid color speed (SCS)

This mode demonstrates 6 colors in a loop with abrupt transition between the frames with adjustable speed using a knob. Rotating the knob clockwise increases transition speed, and vice-versa. Brightness level of all the channels are fixed.

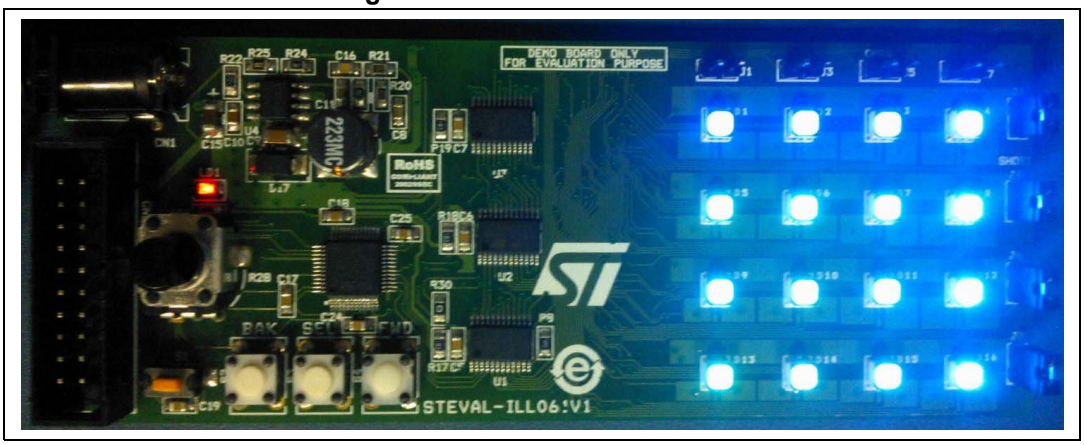
3.3.2 Solid color brightness (SCB)

This mode demonstrates 6 colors in a loop with abrupt transition between the frames with adjustable brightness using a knob. Rotating the knob clockwise increases brightness, and vice-versa. Transition speed is fixed.

3.4 Mode “d”- Error detection demo

The LED1642GW driver is capable of performing three types of error detection, viz. open-circuit, short-circuit and combined error detection. The evaluation board provides the option to simulate and detect these errors as defined in the sections below:

Figure 14. Error detection demo



3.4.1 Open error detection (OED)

In this mode drivers perform open-error detection and display the error. If a defective LED is found, it is signaled by switching on the corresponding blue LED. D1, D2, D3 and D4 green channel open-circuit can be simulated by opening J1, J3, J5, J7, respectively.

3.4.2 Short error detection (SED)

In this mode drivers perform short error detection and display the error. If a defective LED is found, it is signaled by switching on the corresponding blue LED. D4, D8, D10 and D12 red channel short-circuit can be simulated by closing J2, J4, J6, J8, respectively.

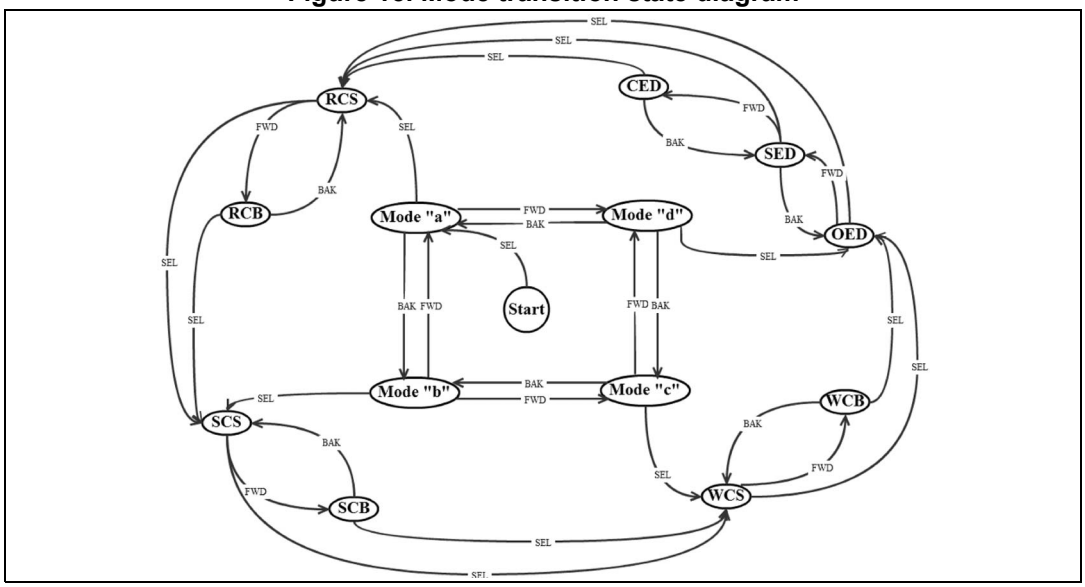
3.4.3 Combined error detection (CED)

In this mode drivers perform both open-error detection and short-error detection simultaneously. If a defective LED is found, it is signaled by switching on the corresponding blue LED. Simulation of errors is the same as in open error detection and short error detection.

For demonstration purposes, an open-circuit error is introduced in green channels and a short-circuit error in red channels. In general, the LED1642GW can perform error detection on any channel and any LED.

3.5 STEVAL-ILL061V1 evaluation board state diagram for transition between modes

Figure 15. Mode transition state diagram

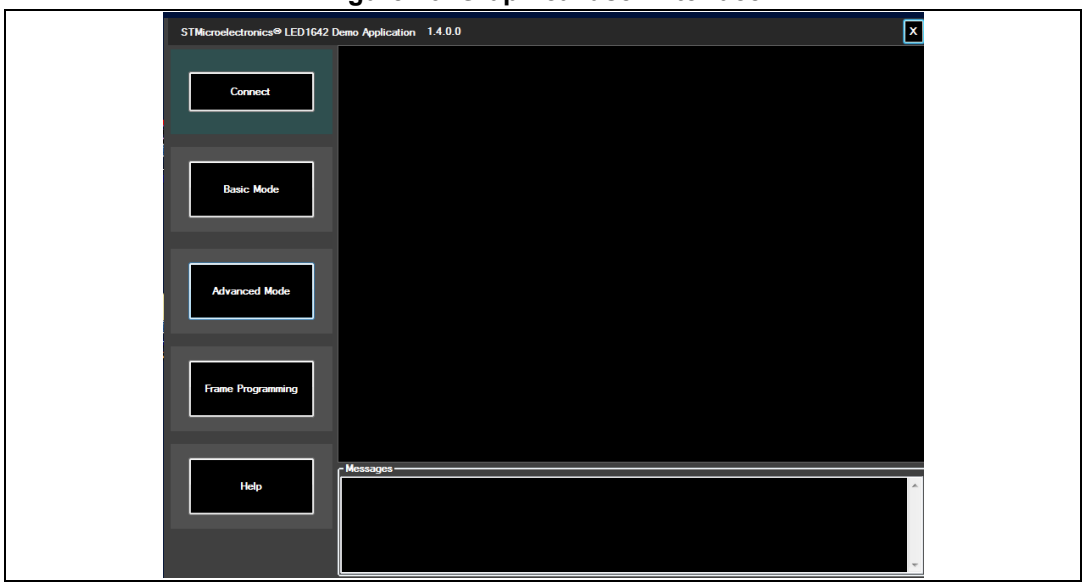


4 GUI mode

The GUI has three modes and a Help section. Modes are classified as:

- Basic mode
- Advance mode
- Frame programming mode

Figure 16. Graphical user interface



The main features of GUI mode are:

- Replication of on-board control buttons to select the mode from the GUI
- Option to select type of error detection (open, short, combined), frequency of performing error detection and error detection representation on a 4x4 LED (mapped to 4x4 LEDs on the evaluation board) map
- Adjustable global brightness for all channels
- Adjustable brightness for 16 individual LEDs
- Bitwise access, both read and write, of the configuration register with one preconfigured default setting
- PWCLK reference clock control from 500 KHz to 24 MHz in 50 steps (frequency intervals are not equally spaced, see *Section 4.3*)
- Frame programming to display any arbitrary pattern consisting of up to 10 frames with variable transition speed
- 4 preconfigured patterns for quick visualization of frame programming mode on the evaluation board

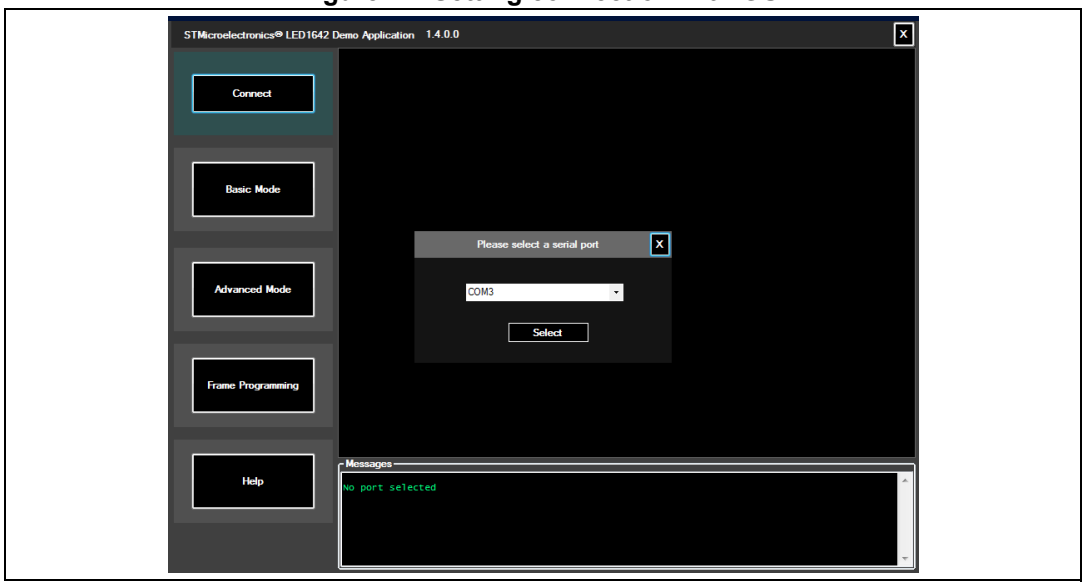
4.1 Graphical user interface setup

The virtual com port driver from ST must be installed on the PC/laptop in order to use the evaluation board GUI. Follow the procedure given in the paragraph that follows.

First, install the setup (.exe) file on a Windows PC/laptop. After installation, the GUI appears as “LED1642 Demo” in the programs list. If the VCP driver is not installed, it can be installed from …\Program Files\ STMicroelectronics\LED1642Demo\ST VCP Driver. Both a 32-bit version and a 64-bit version are included in the setup.

Next, upon launching the GUI, the first page appears as shown in *Figure 17*. At this point connect the evaluation board to the PC and power it up. After the starting sequence, the evaluation board shows “U” in green (*Figure 5*). Now press “Connect”. If the GUI identifies the board, it automatically establishes the connection with the board. Otherwise the GUI prompts the user to select the port to which the board is connected, as shown in *Figure 17* below. Choose the port manually, and press “Select”. When the GUI is able to interact with the board, the “Port is open” message is shown.

Figure 17. Setting connection with GUI



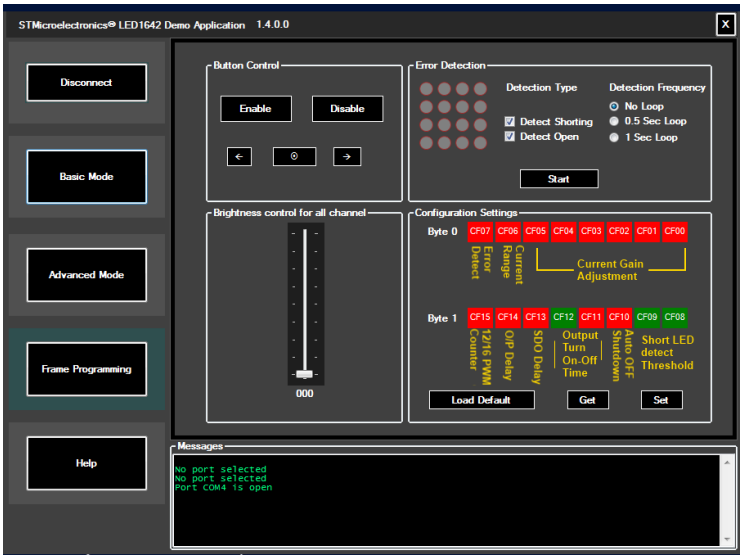
Note: To use the GUI, a Windows machine needs to have virtual COM port driver installed. In the picture shown above, COM3 is shown as an example. On connecting the USB to the PC, VCOM is established on any arbitrary port which has to be identified manually if the GUI does not recognize the board automatically.

4.2 Basic mode

Basic mode has four sections to address different requirements, as follows:

- Button control
- Error detection
- Brightness control for all channels
- Configuration settings

Figure 18. GUI basic mode



4.2.1 Button control

While in GUI mode, toggling between preconfigured demos can be handled by buttons in this section. These control buttons are a replication of the on-board BAK, SEL & FWD button.

By default, the GUI disables the buttons on the board. These can be enabled or disabled manually by pressing the enable or disable buttons, respectively.

4.2.2 Error detection

The error detection section demonstrates errors (if any) present in the LEDs on a 4x4 LED matrix. Error detection frequency can be selected from three options viz. No loop (error detection is performed once and the results are displayed), 0.5 second loop (error detection is performed every 0.5 s by the drivers and the results get update in real time) and similarly 1 second loop.

Also, detection type can be chosen by checking the appropriate check box. Checking both of the boxes performs combined error detection, while nothing is done if both boxes are unchecked.

4.2.3 Brightness control for all channels

Brightness for all the channels is simultaneously varied by varying the brightness control for all channel slider. Brightness can be varied in 256 steps (0% to 100%) using the slider.

4.2.4 Configuration settings

The configuration settings section represents the 16-bit configuration register of the LED1642GW driver. Bits can be set/reset by clicking on them.

- The Load default button loads the default setting value on the GUI
- The Set button configures the drivers for the value which is shown on the GUI
- The Get button reads the configuration register value from the driver and shows it

At all times, all three drivers have the same configuration register value. There is no option to program different configuration register values among the drivers.

4.3 Advanced mode

Advance mode has two sections: channel brightness control for individual adjustment of each LED brightness and PWCLK slider to control the reference PWCLK clock.

Similar to brightness control for all channels in basic mode (*Section 4.2.3*), different brightness control sliders are present for each LED.

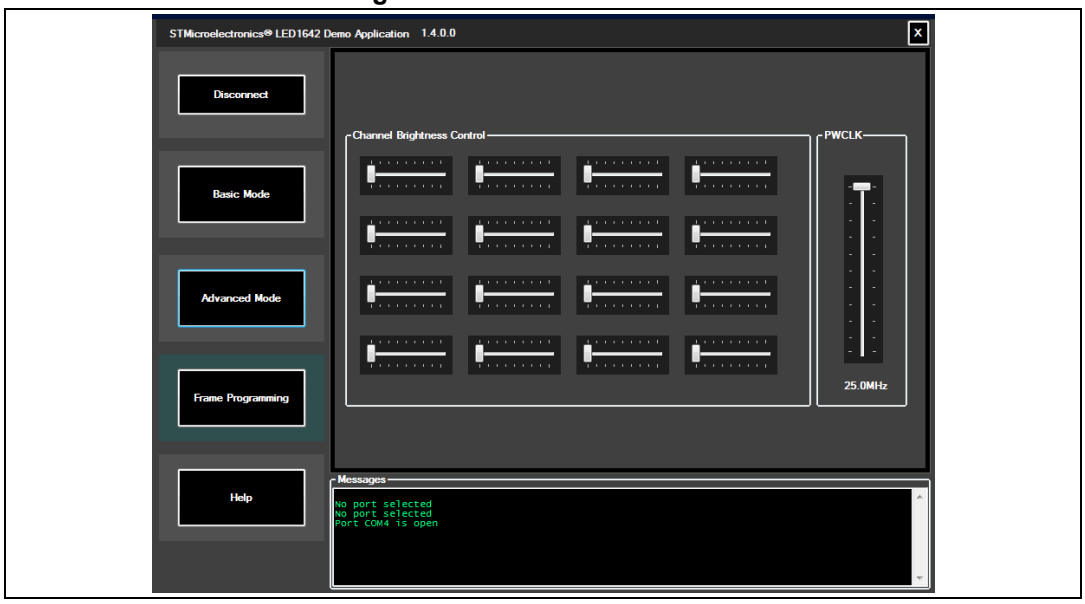
The PWCLK slider controls the reference clock from 500 KHz to 24 MHz in 50 steps according to the formula:

Equation 1

$$PWCLK\,frequency = \frac{SYSTEM\ CLOCK}{1 + (101 - 2{*}PWCLK\ slider)}$$

where, SYSTEM clock is equal to 48 MHz and the initial value of the PWCLK frequency is 24 MHz.

Figure 19. GUI advanced mode

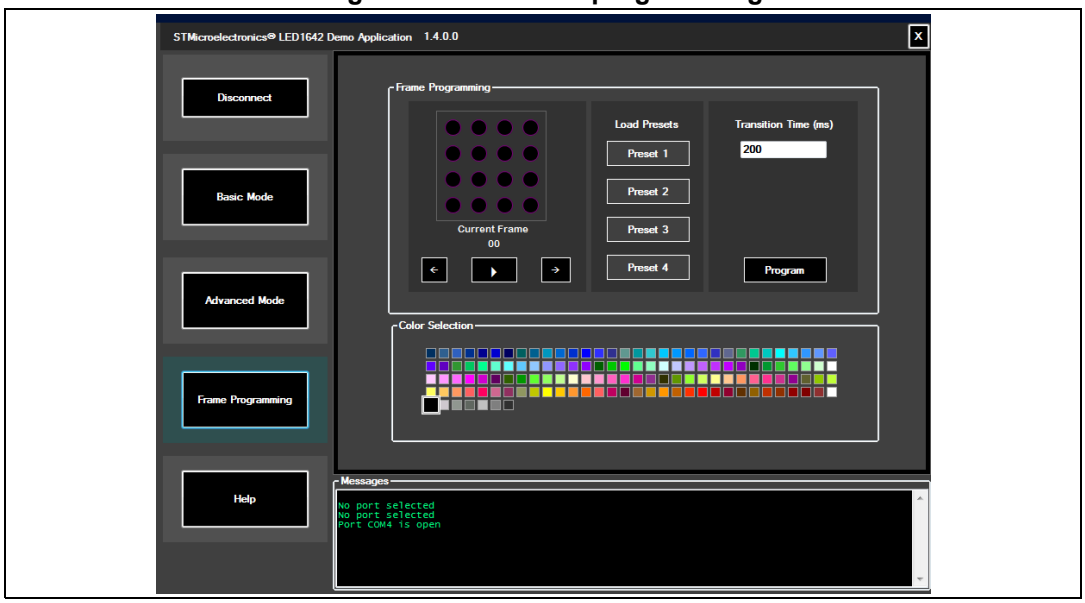


4.4 Frame programming

Frame programming displays the feature of user-defined RGB patterns in a round-robin sequence on the evaluation board. This mode contains a set of 10 independent frames and each frame represents one instance of colorful representation of LEDs on the board.

In this mode, either the frames can be designed by the user, or preconfigured frame patterns can be selected using presets. Transition time between the frames in milliseconds (approximate value) is set by the value in the transition time text box.

Figure 20. GUI frame programming



Note: For frame programming, RGB color levels are rendered directly from the color selected in the GUI. Actual perception might be different compared to the selection because of different luminous intensity of red, green and blue channels. Fine-tuning might be required for proper visualization.

4.4.1 Designing of frames

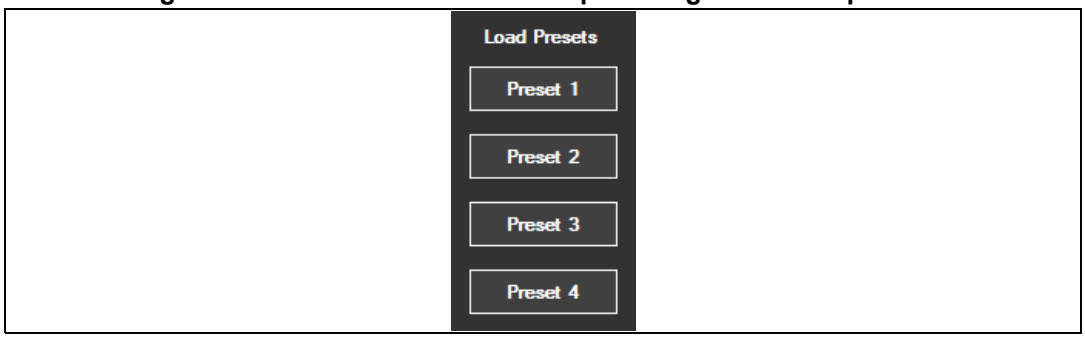
A frame on the GUI represents LEDs on the evaluation board in a similar fashion. Each LED representation is configurable for various RGB color values given in the color selection pane. Below are the steps for designing the frames and demonstrating them on the evaluation board:

- To design a frame choose a color from the pane and click on the LED(s) to configure them for the selected color
- There can be maximum of 10 frames (00 to 09), the right arrow button increments the frame number, and the left arrow button decrements it.
- Each frame is designed separately for the required color pattern in a similar way
- The Play button plays the sequence of frames in the GUI to visualize the whole pattern to be displayed on the board
- Set required Transition Time between the frames and press “Program”

4.4.2 Using a preconfigured frame pattern

In frame programming mode, four preconfigured frame patterns, called presets, are provided for quick demonstration of this feature.

Figure 21. Preset buttons to load a preconfigured frame patterns



Preset1, Preset2, Preset3 and Preset4 can be loaded by clicking on the corresponding preset button. The images below show the frame configurations for different presets. Choosing any one of them configures the frames as shown.

Figure 22. Preset 1

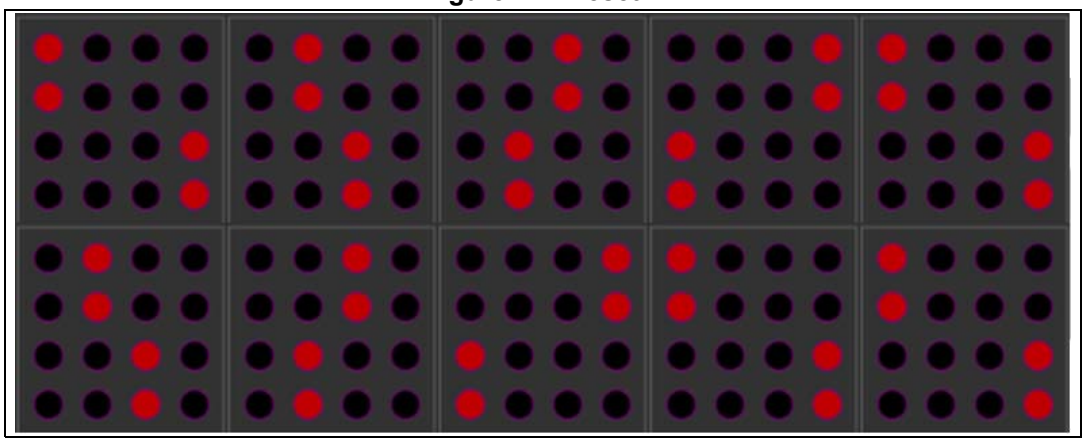


Figure 23. Preset 2

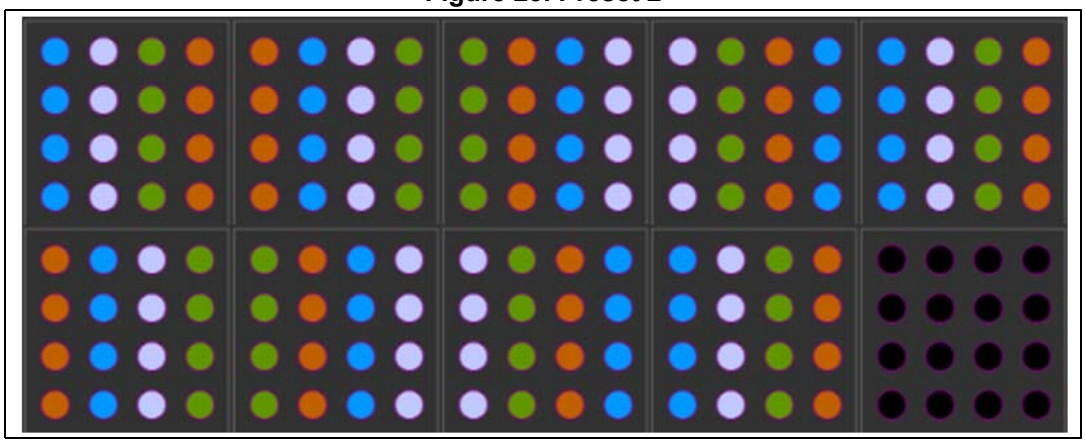


Figure 24. Preset 3

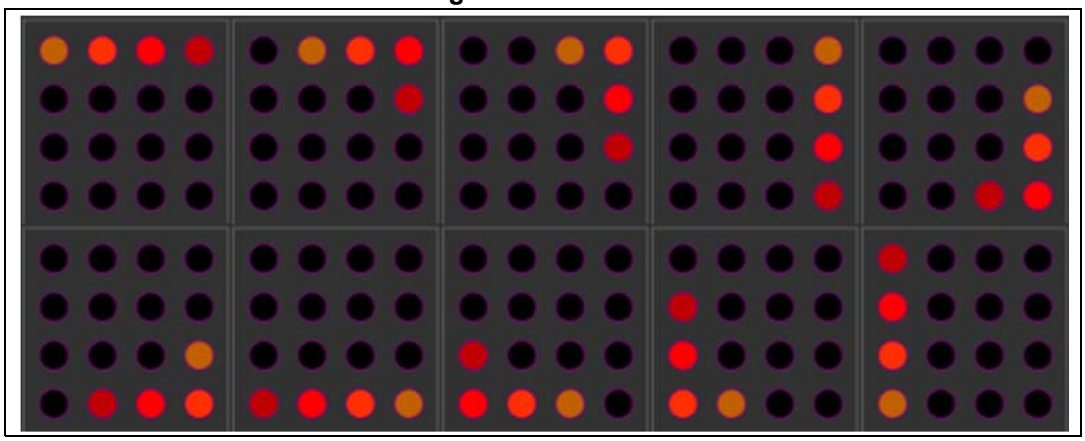
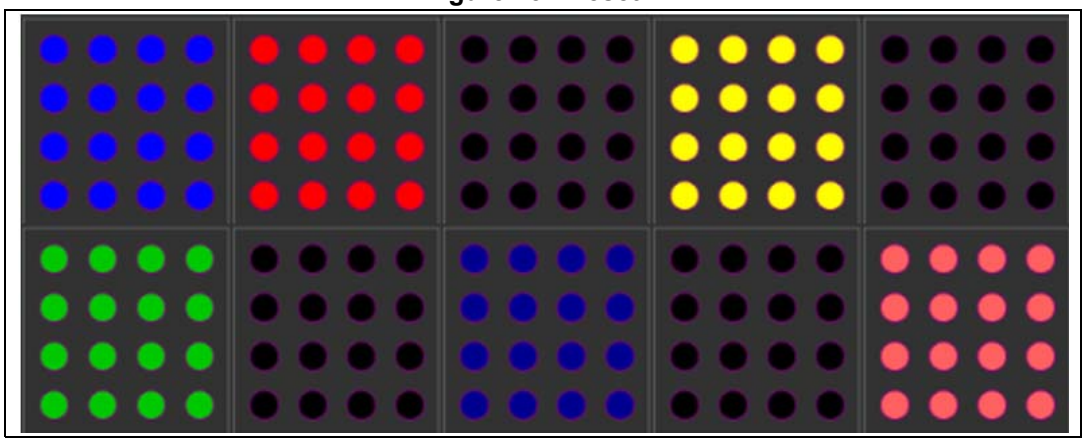


Figure 25. Preset 4



5 Thermal behavior

The LED1642GW is available in QFN24, TSSOP24, TSSOP24-EP and QSOP24 packages. Of these packages, the TSSOP24 Exposed Pad has the least thermal resistance at 37.5 °C/W. Average forward voltage drop of the red, green and blue channels are 2, 3.2 and 3.2 V, respectively. Maximum channel current is configured for 24 mA. Red channels have series resistance of 47 E for limited dissipation in the red channel driver because forward voltage drop of the red channel is less than that of the blue channel or green channel driver. The image below shows the evaluation board and corresponding thermal image at the maximum current in all the channels (the TSSOP24-EP package is mounted on the evaluation board):

Figure 26. STEVAL-ILL061V1 evaluation board

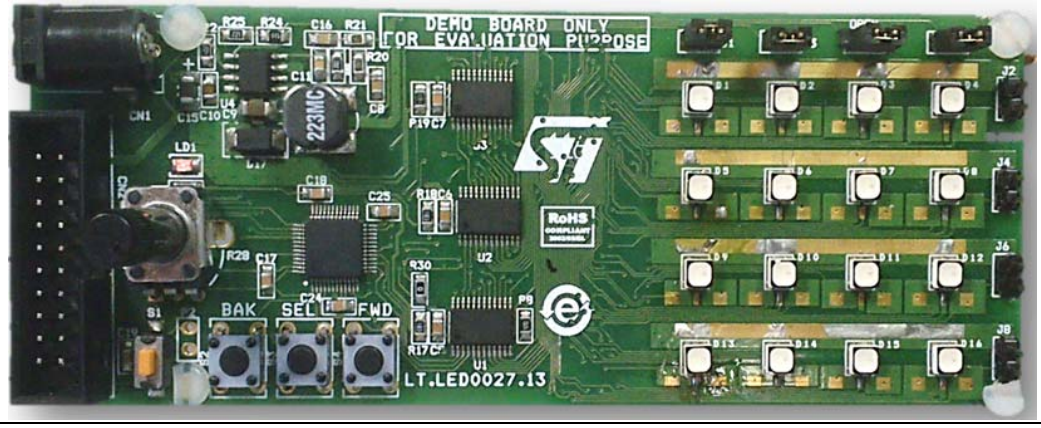
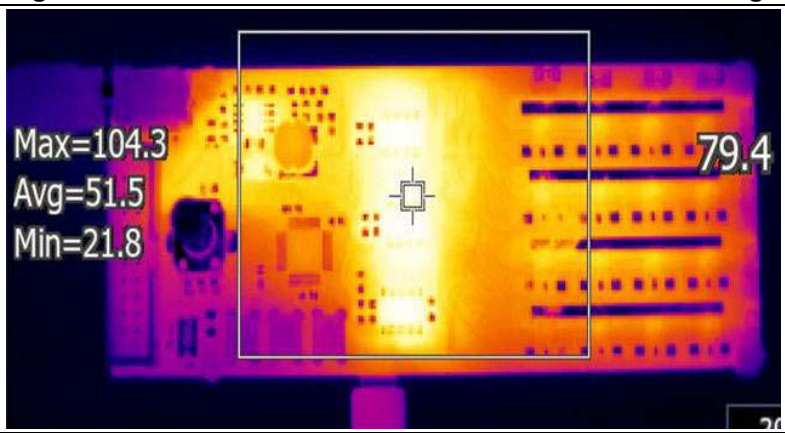


Figure 27. STEVAL-ILL061V1 evaluation board thermal image



6 Schematic diagrams

Figure 28. Power supply

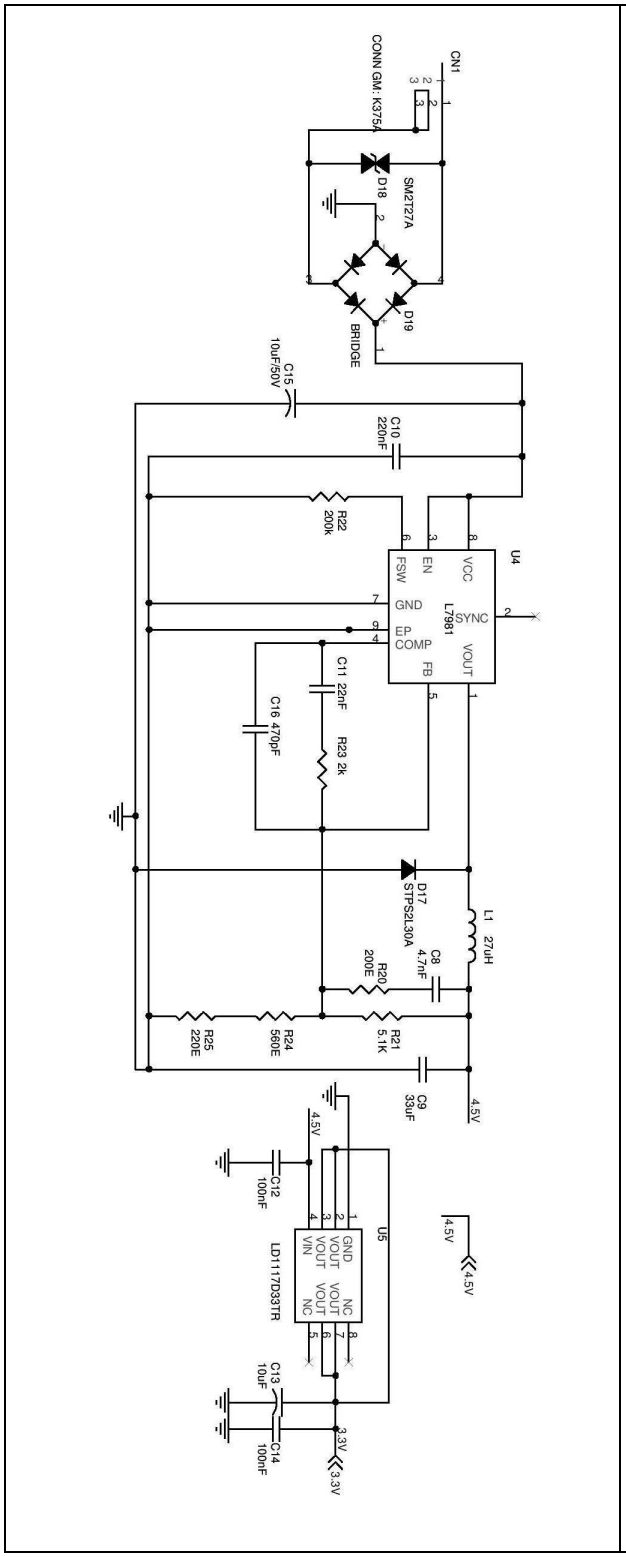


Figure 29. LED drivers

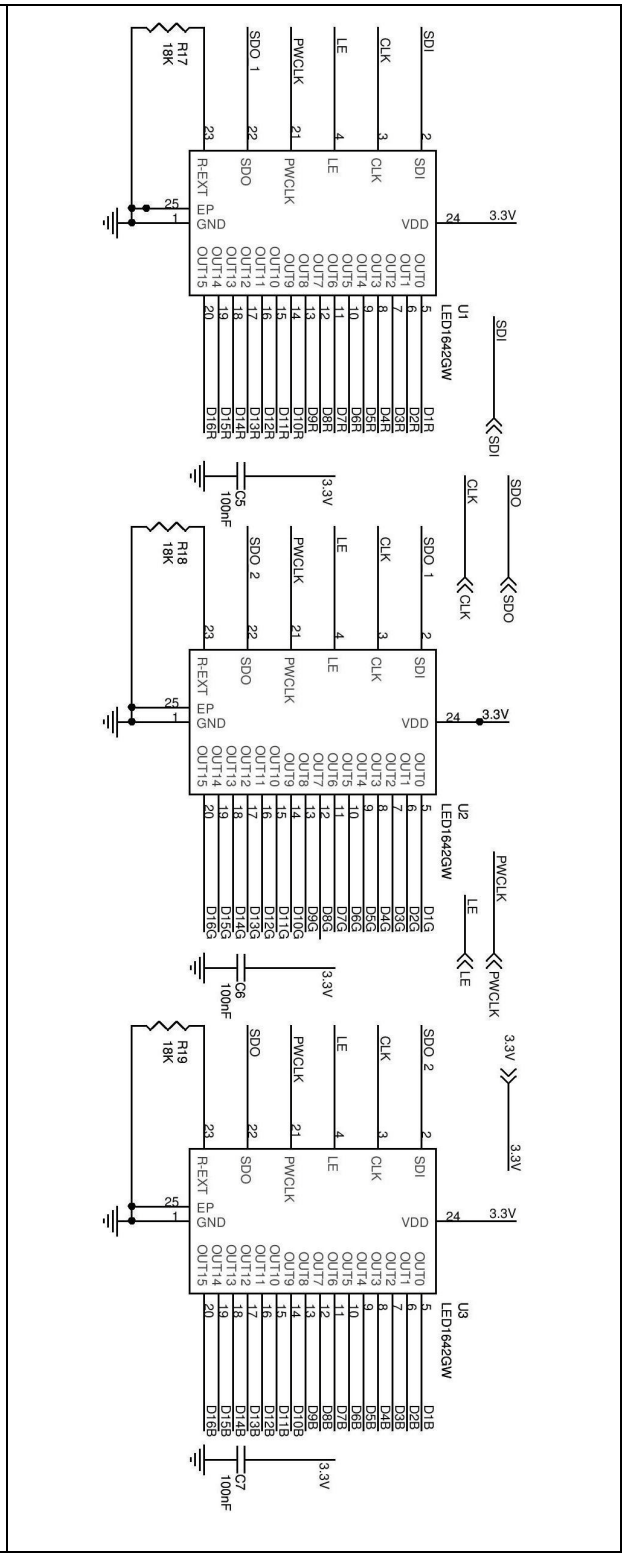


Figure 30. Microcontroller, USB, JTAG connector, buttons, knob

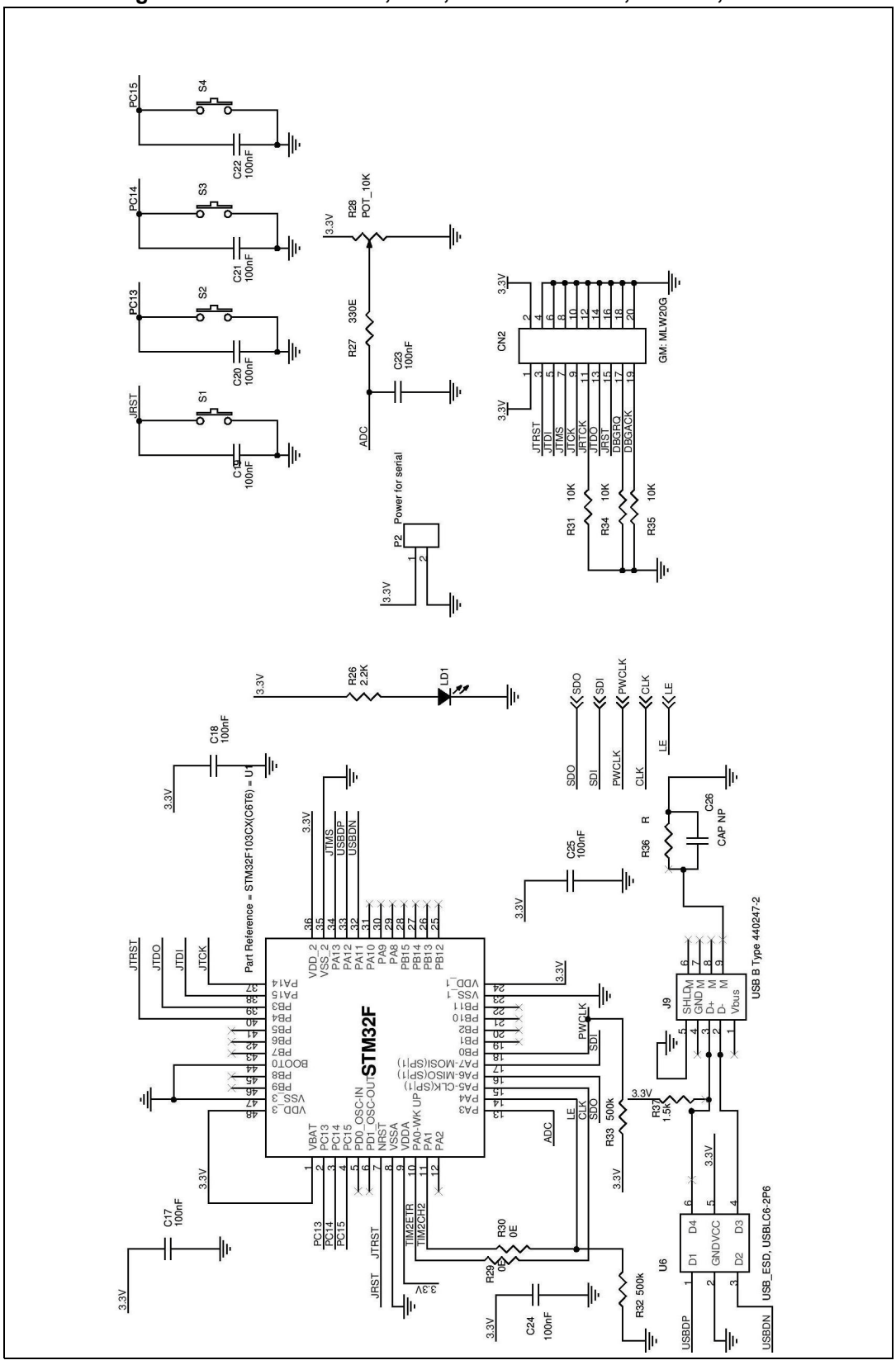
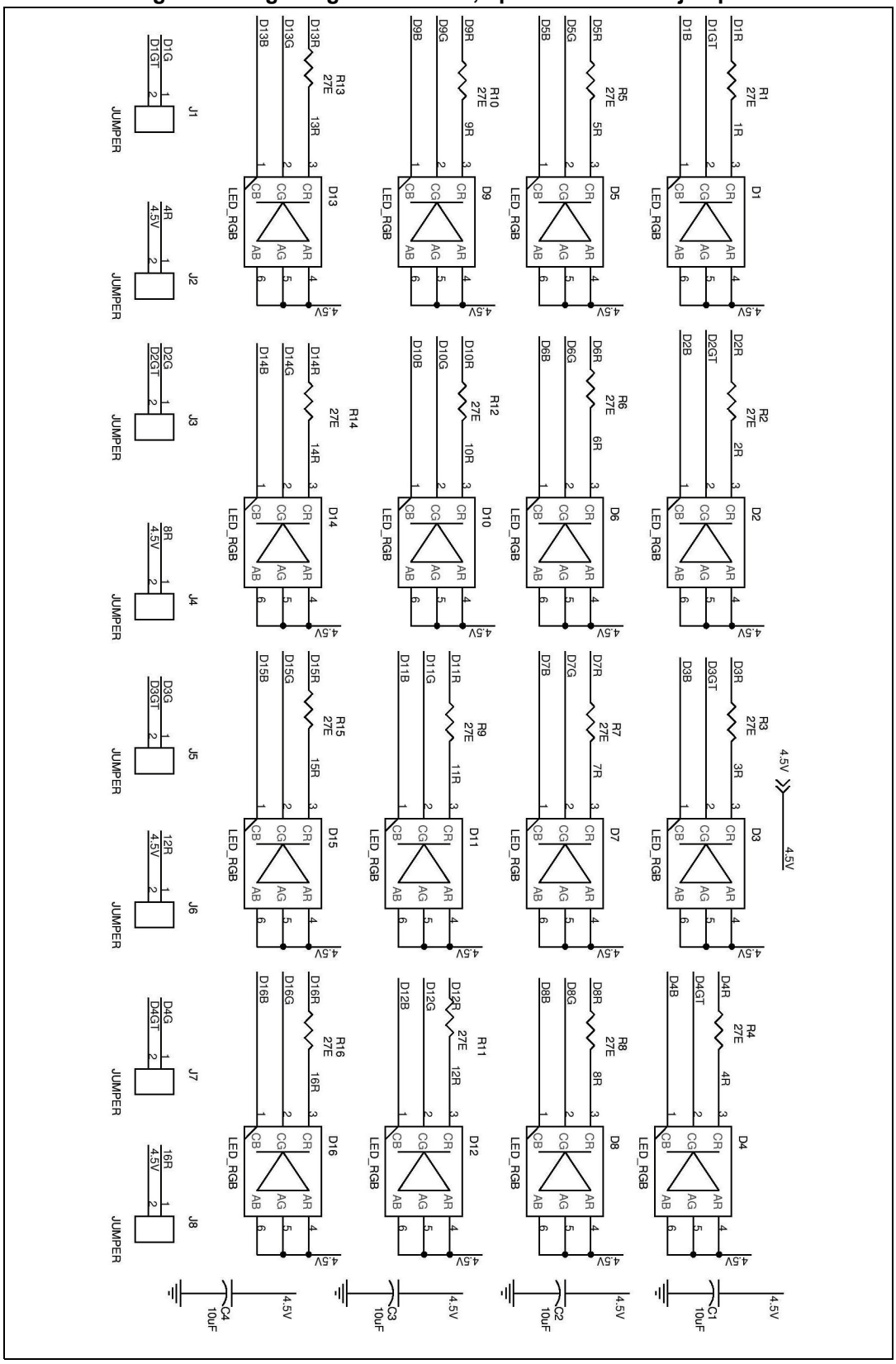


Figure 31. High brightness LEDs, open/short-circuit jumpers



7 Bill of materials

Figure 32. BOM (1 of 3)

Category	S. No.	Reference Designator	Component Description	Package	Manufacturer	Manufacturer's ordering code / Orderable Part Number or Equivalent	Supplier	Supplier Ordering Code	Quantity
ST Devices	1	U1,U2,U3	LED1642GW	TSSOP24-EP	ST	LED1642GW	ST	LED1642GW	3
	2	U4	L7981	HSOP8	ST	L7981ATR	ST	L7981ATR	1
	3	U5	LD117D33	SO-8	ST	LD1117D33TR	ST	LD1117D33TR	1
	4	U6	USBLC6-2P6	SOT-666	ST	USBLC6-2P6	ST	USBLC6-2P6	1
	5	STM32F103CX	STM32F103C6T6	LQFP48	ST	STM32F103C6T6TR	ST	STM32F103C6T6TR	1
	6	D3	STPS2L30	SMA	ST	STPS2L30A	ST	STPS2L30A	1
	17	D18	SM2T27	Stmite	ST	SM2T27A	ST	SM2T27A	1
Connectors/ Jumpers	7	J1,J2,J3,J4, J5,J6,J7,J8	2 pin jumper	Through hole, 2.54 mm pitch	FCI	68602-108HLF or equivalent	ST	649-68602-108HLF	8
	8	J9	USB B type	USB female conn	OnShore Tech	USB-M26FTR or equivalent	Digikey	ED2992TR-ND	1
	9	CN1	DC Jack	Female conn	CUI	PJ1-021 or equivalent	Digikey	CP1-021-ND	1
	10	CN2	JTAG	Box conn, male	TEConnectivity	2-1761679-7 or equivalent	Digikey	2-1761679-7-ND	1
Inductance	12	L1	22uH	Surface Mount	Murrata Power	22R223MC	Mouser	580-22R223MC	1
	13								
Switches	14	S1	SW PUSH BUTTON	Switches					1
	15	S2,S3,S4	Push Button	Through hole	C&K	611-PTS645SM952	Mouser	PTS645SM95-2 LFS	3
Diodes/LEDs	16	LD1	LED red colour	SMD0805	Lite-On Inc	LTST-C170KRKT	Digikey	160-1415-2-ND	1
	18	D19	Diode bridge	DFS	Fairchild	DF01S	Mouser	512-DF01S	1
	19	D1,D2,D3,D4, D5,D6,D7,D8, D9,D10,D11,D12, D13,D14,D15,D16	RGB LED	PLCC6	CREE	LL4148CLX6A-FKB-CJNNRFJBB7A363	Mouser	941-X6AFKBCJNNRFJ7A3	16

Figure 33. BOM (2 of 3)

Resistances	20	R1,R2,R3,R4,R5,R6, R7,R8,R9,R10,R11, R12,R13,R14,R15,R 16	47E	SMD0805	Panasonic - ECG	ERJ-6GEYJ470V or equivalent	Digikey	P47ACT-ND	16
	21	R17,R18,R19	18K	SMD0805	Panasonic - ECG	equivalent	Digikey	P18KA-ND	3
	22	R20	200E	SMD0805	Panasonic - ECG	ERJ-6GEYJ201V or equivalent	Digikey	P200A-ND	1
	23	R21	5K1	SMD0805	Panasonic - ECG	ERJ-6GEY512V or equivalent	Digikey	P5.1KACT-ND	1
	24	R22	200K	SMD0805	Panasonic - ECG	ERJ-6GEYJ204V	Digikey	P200KA-ND	1
	25	R23	2K	SMD0805	Panasonic - ECG	ERJ-6GEYJ202V or equivalent	Digikey	P2.0KACT-ND	1
	26	R24	560E	SMD0805	Panasonic - ECG	ERJ-6GEYJ561V or equivalent	Digikey	P560ATR-ND	1
	27	R25	220E	SMD0805	Panasonic - ECG	ERJ-6ENF221V	Digikey	P220CCT-ND	1
	28	R26	2K2	SMD0805	Panasonic - ECG	ERJ-6GEYJ222V or equivalent	Digikey	P2.2KACT-ND	1
	29	R27	330E	SMD0805	Panasonic - ECG	ERJ-6GEYJ331V or equivalent	Digikey	P330MACT-ND	1
	30	R28	POTENTIOMETER 10K	Through hole	ALPS	RK09K1130A70	Mouser	688-RK09K1130A70	1
	31	R29,R30	0E	SMD0805	Panasonic - ECG	ERJ-6GEY0R00V or equivalent	Digikey	P0.0ACT-ND	2
	32	R31,R34,R35	10K	SMD0805	Panasonic - ECG	ERJ-6GEYJ103V or equivalent	Digikey	P10KACT-ND	3
	33	R32,R33	DNM	SMD0805	Panasonic - ECG	ERJ-6GEYJ272V or equivalent	Digikey	P2.7KACT-ND	2
	34	R36	100K	SMD0805	Panasonic - ECG	ERJ-6GEYJ104V or equivalent	Digikey	P100KACT-ND	1

Figure 34. BOM (3 of 3)

Capacitors	35	C1,C2,C3,C4,C13	10uF	SMD0805	Panasonic - ECG	ECJ-2FB1A106K or equivalent	Digikey	PCC2403CT-ND	5
	36	C5,C6,C7,C12,C14, C17,C18,C19,C20,C 21,C22,C23,C24, C25	100nF	SMD0805	TDK	CGA4F2X7R1H104K or equivalent	Mouser	810-CGA4F2X7R1H104K	14
	37	C8	4.7nF	SMD0805	Taiyo Yuden	JMK212BJ476MG-T or equivalent	Digikey	587-1779-1-ND	1
	38	C9	33uF	SMD1206	TDK	C3216X5R1C336M or equivalent	Mouser	810-C3216X5R1C336M	1
	39	C10	220nF	SMD0805	Taiyo Yuden	UMK212B7224KG-T or equivalent	Digikey	587-1287-1-ND	1
	40	C11	22nF	SMD0805	Taiyo Yuden	QMK212B7223KG-T or equivalent	Digikey	587-1272-1-ND	1
	41	C15	10uF/50V	SMD1206	TDK	C3216X5R1H106k or equivalent	Mouser	810-C3216X5R1H106K	1
	42	C16	470pF	SMD0805	TDK	equivalent	Mouser	810-CGA4C2C0G2A471J	1
	43	C26	4.7nF	SMD1206	TDK	CGA4C2C0G1H472J or equivalent	Mouser	810-CGA4C2C0G1H472J	1

8 Revision history

Table 2. Document revision history

Date	Revision	Changes
16-May-2014	1	Initial release.

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