LEDs Array Reference Board Design

New High Brightness LED applications such as Displays, Information panels, Signs, Traffic signals, Automotive lighting and Advertising are becoming more and more popular. For such applications new HB LED drivers with constant current outputs were designed. The constant LED current guarantees the same brightness for all LEDs and gives a cost advantages in lighting system solutions, because no external resistors for each individual LED are needed. In this application note it is described an easy design solution to drive an array of High Brightness LEDs, using the STP16CP596 and STP16CL596 LED drivers.

1 INTRODUCTION

Two reference boards (80LEDs and 32LEDs) were designed to show a solution for driving High Brightness LED (HB LED) arrays. In the first board the array of 80 blue HB LEDs are arranged in a matrix 5 x 16. This matrix is driven by five 16 channel STP16CL596 driver. It is possible to implement a short moving text. Also all LEDs in the display can be turn ON simultaneously by a switch in order to demonstrate the same brightness of all LEDs, which is achieved by the same sink current in all channels. The second board is smaller (matrix 4 x 8 LEDs driven by STP16CP596) and includes a DC/DC converter for various supply voltages from 5 up to 35V.

The new LED drivers as STP16CL596, STP16CP596 and STP08CL596 are monolithic, low voltage 8-bit or 16-bit shift registers designed for driving LED and LED panel displays. Thanks to these drivers the output LED current is constant and can be very precisely set by just one external resistor, controlling in this way the light intensity of LEDs. The STPxxCx596 guarantees up to 16V output driving capability, allowing designers to connect more LEDs in series. The high clock frequency, 25MHz also satisfies the system requirement of high volume data transmission. Both designs are controlled by the microcontroller ST7LITE09, which provides full text motion control, brightness regulation through PWM and control of text speed. A 3.3V supply voltage for the micro and drivers is created by a linear voltage regulator LE33 or L78L33.

Rev. 2

2 BLOCK SCHEMATIC

The block schematic of the LEDs array reference board is shown in Figure 1. This block diagram shows the universal ST system solution for driving an array of LEDs. The number of LEDs can be increased by adding additional drivers to cascade. The input voltage is connected to the anodes of all HB LEDs. Its value is very important due to the power dissipation in the drivers. A detailed explanation is described in section 4 REDUCING POWER DISSIPATION ON CHIP. The LEDs´ cathodes are connected to ground through constant current sinks. The value of the constant current is set by only one external resistor. The DC/DC converter is represented by simple linear controller LE33 or L78L33 and provides 3.3V supply voltage for the micro and the LED drivers. The switch mode power supply SMPS DC/DC, using L5970D step down converter, is designed to increase the range of supply voltage (5 up to 35V), efficiency and performance. A detailed description of the SMPS design is given in [3].

The control unit in this application is a microcontroller, which sends data through the serial peripheral interface (SPI) to the shift registers. The data are shifted bit by bit to the next driver with the falling edge of the clock frequency (the maximum communication frequency for this driver is 25MHz).

The control panel consists of the switch and two potentiometers. The switch changes the modes and the potentiometers allow changing the brightness and text speed (blinking speed).

Figure 1. Block Diagram
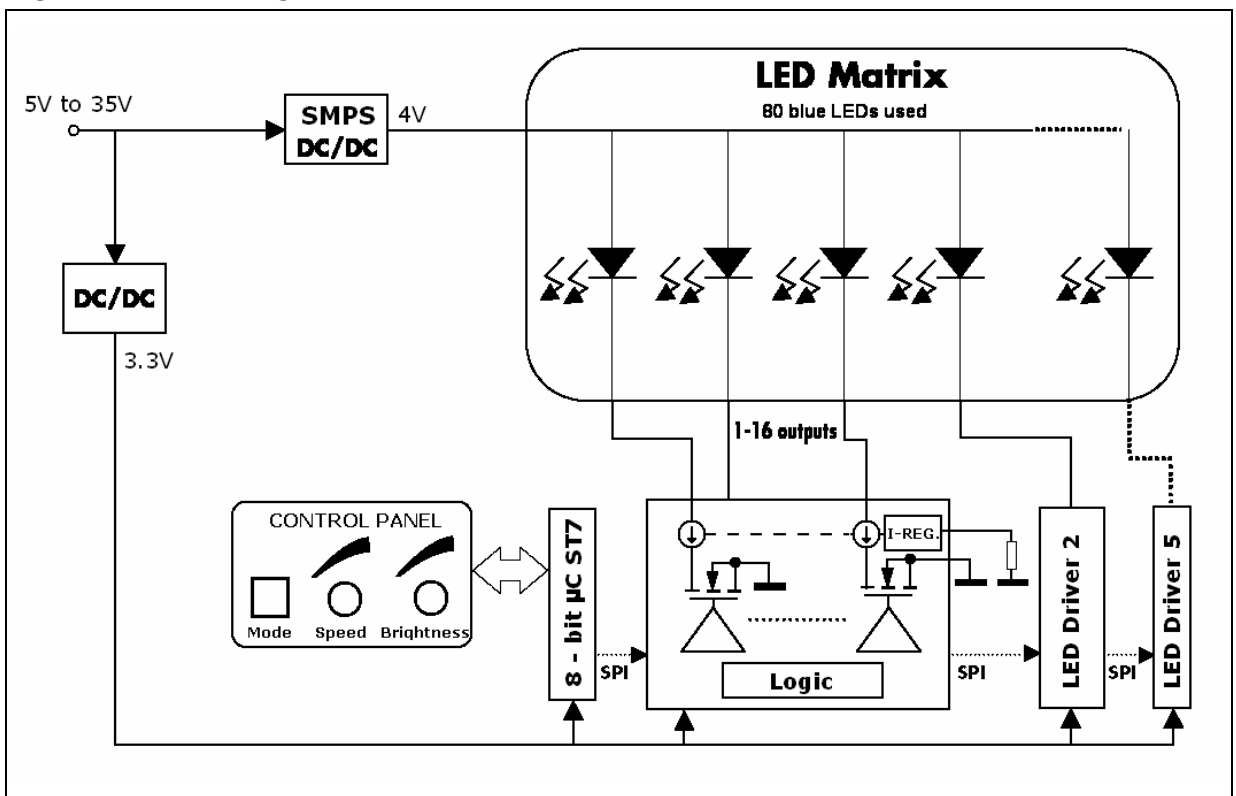
3 TIMING DIAGRAM

The typical timing diagram is shown in Figure 2. There are DATA, CLOCK and LATCH waveforms depicted. The data are changed with falling edge of the clock frequency. For example, in Figure 2 one byte (01101001) can be seen. When all data are written to the drivers through SPI, the micro sets latch input terminal (LE) pin "log 1" and rewrites the data to the storage registers. In the next step the LE pin is grounded and so next data can be transmitted to the shift registers without changes in the output stage. The data in storage registers are converted to the output constant current stages by output enable (EO) pin. Thanks to this EO pin the brightness can be regulated through PWM signal. Both LEDs array reference designs have adjustable delay time by potentiometer after "latch signal" implemented. Thanks to this feature the blinking speed can be regulated (time between sending data packets is changed).

Figure 2. Timing diagram
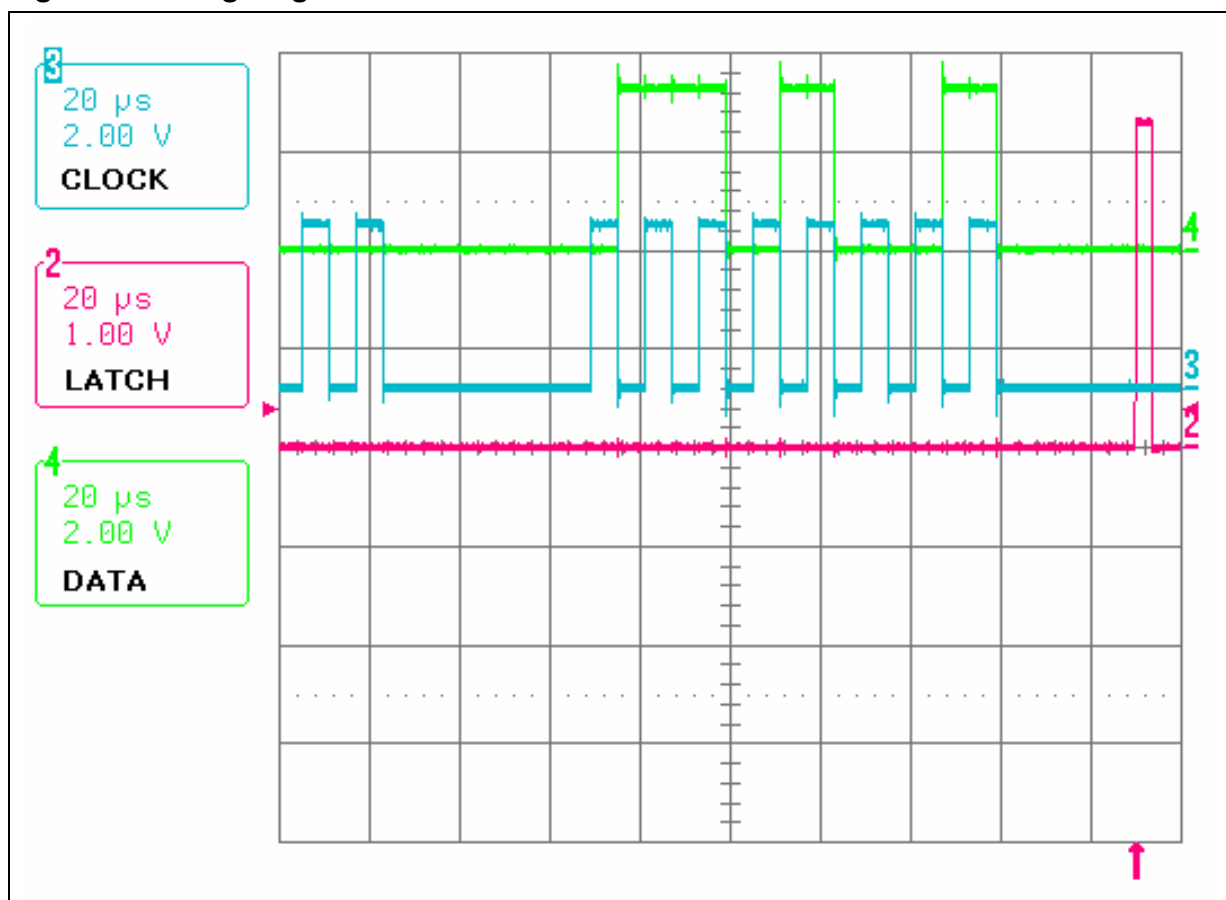
4 REDUCING POWER DISSIPATION ON CHIP

One of the most important considerations in this application is the calculation of the maximum power dissipation on the driver chip. The maximum power consumption can be calculated with the ambient temperature and thermal resistance of the chip. The thermal resistance depends on the type of package and can be found together with the maximum allowed junction temperature in the datasheet [1]. The maximum allowable power consumption of this device is calculated as follows:

$$P_{d\,max} = \frac{T_{j\,max} - T_a}{R_{thja}}$$

$P_{d\,max}$ …… maximum power dissipation [W]

T_a ………… ambient temperature [°C]

$T_{j\,max}$ ……. maximum junction temperature [°C]

R_{thja} ……… thermal resistance junction to ambient [°C/W]

The maximum forward current for each type of LED is written in its datasheet and the lower value has to be set. Each output channel of the driver is operating as linear current sink. As the sink current for each output of LED driver is set as constant by an external resistor, the power dissipation in the chip is dependant on the value of LEDs supply voltage (V_c) minus the forward voltage drop of the LEDs. For optimizing power dissipation on chip it is recommended to use the supply voltage for LEDs as low as possible. An example how to calculate the power dissipation on chip is in Figure 3. The equation for this basic connection is as follows:

$$P_{tot} = I_c * U_c + I \sum_{i=1}^{\#outputs} (V_c - n_i V_F)$$

P_{tot} ………… power dissipation on chip [W]

I_c …………… supply current for driver [A]

U_c …………… supply voltage for driver [V]

I ……………… constant LED current set by external resistor [A]

#outputs…… number of outputs

V_c …………… LED supply voltage [V]

n_i …………… number of serial connected LED for each output

V_F …………… LED forward voltage [V]

Figure 3. General Configuration
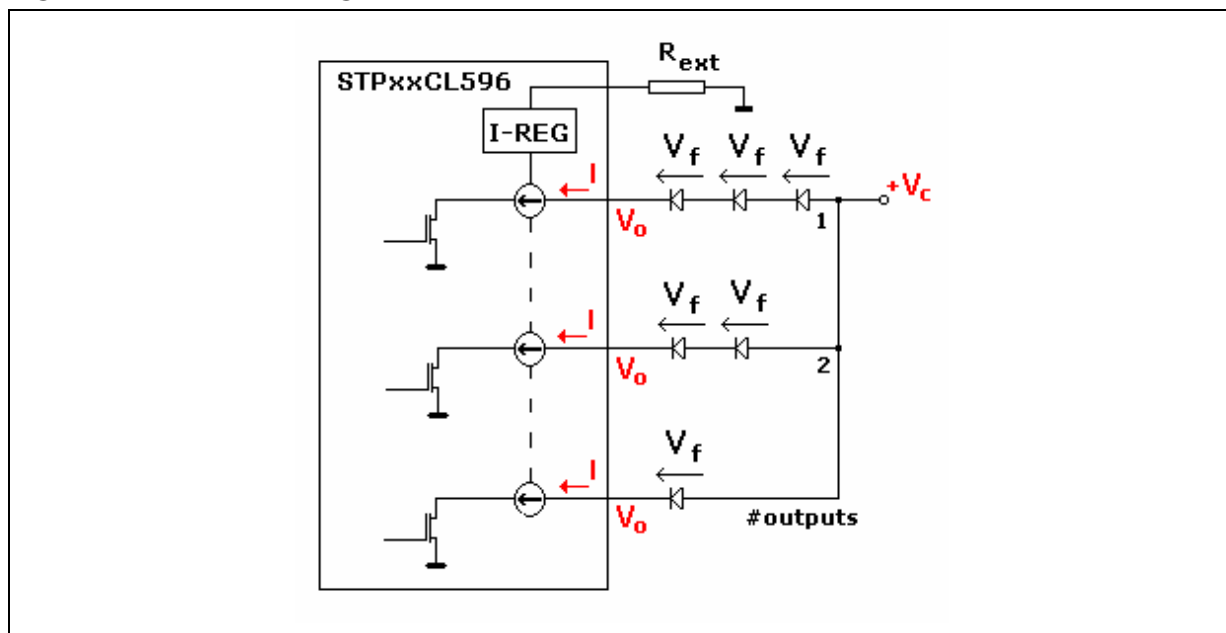
When only one LED is connected to each output (this is the most typical configuration which is used in LEDs array reference board as well) the equation can be reduced as follows:

$$P_{tot} = I_c * U_c + \#outputs * I * (V_c - V_F)$$

As stated before only the LED supply voltage V_c is variable. Thus the right choice is LED supply voltage V_c about 0.5V higher than V_F or n*V_F for n LEDs connected in series.

If a PWM signal controls the brightness of LEDs, the total power dissipation on chip is calculated:

$$P_{tot} = I_c * U_c + \#outputs * I * (V_c - V_F) * D$$

, where D is the duty cycle.

If there is no possibility to get proper value of LED supply voltage in an application, an external resistor R in series with each LED has to be connected for limiting the power dissipation on chip as it is shown in Figure 4. The power dissipation on chip is decreased due to this fact as follows:

$$P_{tot} = I_c * U_c + \#outputs * I * (V_c - (V_F + I * R))$$

Figure 4. Configuration with Resistors
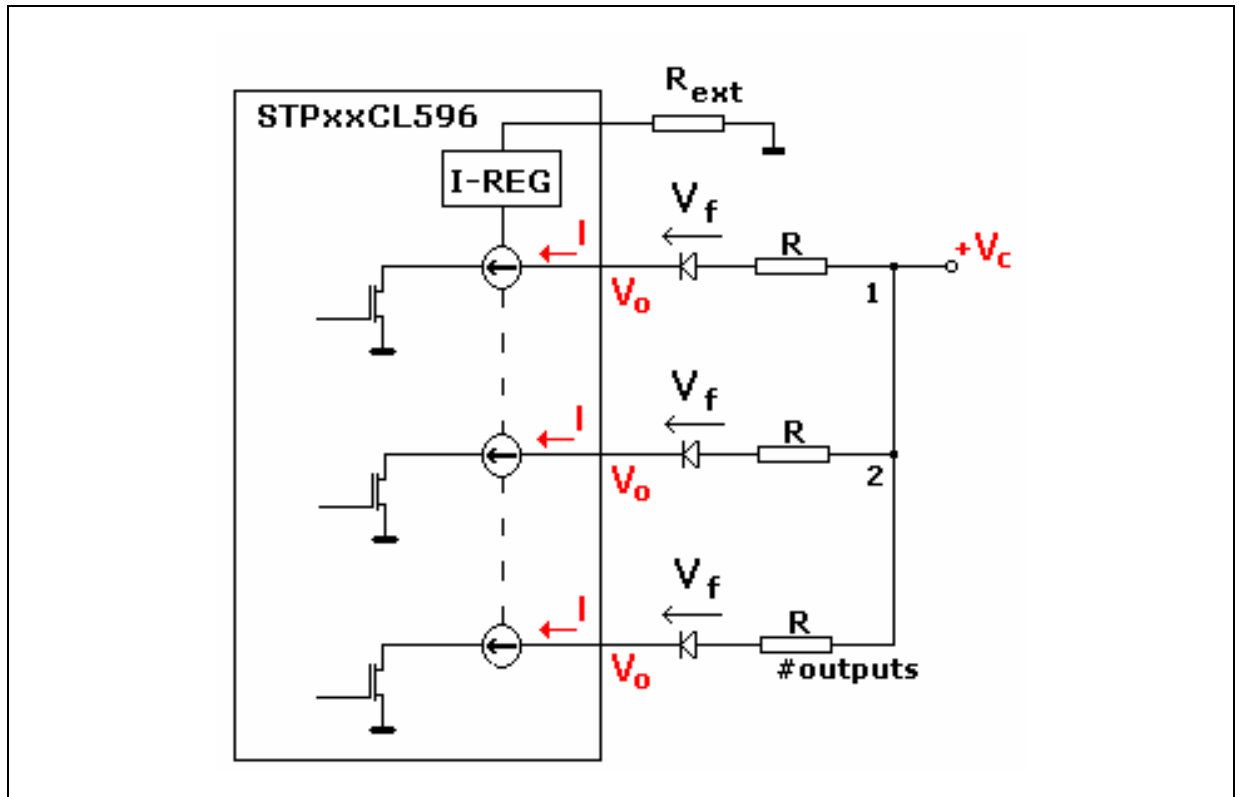
5 COMMON DRAIN OUTPUTS CONFIGURATION

As mentioned above the STPxxCx596 is focused on driving High Brightness LEDs. Their maximum forward current of HB LEDs can vary from 20mA to several hundred mA. A typical current value for Super HB LED is 350mA. Thanks to common drain configuration the outputs can be connected together as it is shown in Figure 5. This increases the performance and current capability of this driver. This configuration allows driving many different type of HB LED even with the limited current per output.

Figure 5. Common Drain Outputs Configuration
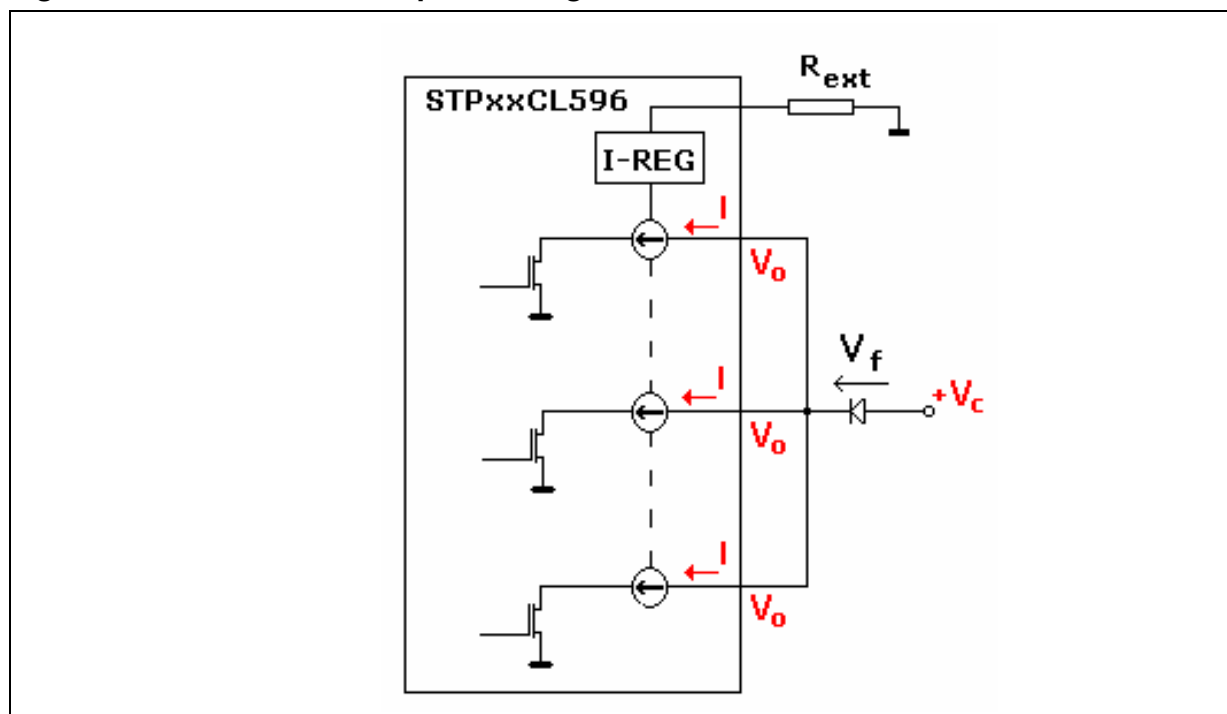
6 LED ARRAY REFERENCE DESIGNS

Two LED ARRAY REFERENCE DESIGNS based on the STP16CL596 and STP16CP596 have been designed. One with 80LEDs and one with 32LEDs. In the following section these two designs and their differences are briefly described.

6.1 80LEDS ARRAY REFERENCE DESIGN

Figure 6. 80LEDs Array Reference Board

The 80LEDs array reference board is shown in the Figure 6 and its block schematic description is in section 2 BLOCK SCHEMATIC. The only simplification in this reference board is that the SMPS DC/DC converter is not included. Therefore the supply voltage should be in the range of 4 to 5V.

6.1.1 APPLICATION SCHEMATIC

The detailed application schematic of this design is shown in Figure 7. Five STP16CL596 LED drivers with 16 outputs are controlled by the microcontroller ST7LITE09. The microcontroller provides the clock frequency (SCK pin), serial data (MOSI pin), PWM signal (PWM pin) and latch signal (PA0 pin). The clock frequency in this application is 633KHz and PWM signal for brightness regulation is 619Hz. The resistors R1 to R5 (one for each Driver) set the constant current for all outputs. Their value is 1.3kΩ and they set the constant sink current to approximately 10mA (for more info see [1]). The analog voltage values from the trimmers R6 and R8 are measured and converted by the micro´s ADC to the digital reference signal. The micro sets the PWM signal for brightness and data time delay for text speed control accordingly.

6.1.2 BOM

Item	Quantity	Reference	Part
1	8	C1, C2, C3, C4, C5, C7, C8, C9	100nF
2	1	C6	10µF
3	1	C10	2.2µF
4	80	D1 - D80	LED
5	5	J1, J2, J3, J4, J5	STP16CL596
6	1	J6	ICP
7	1	J7	Connector
8	5	R1, R2, R3, R4, R5	1k3
9	3	R6, R7, R8	10K
10	1	SW1	SW PUSH BUTTON
11	1	U1	ST7lite09
12	1	U2	LE33/SO

Figure 7. Application Schematic
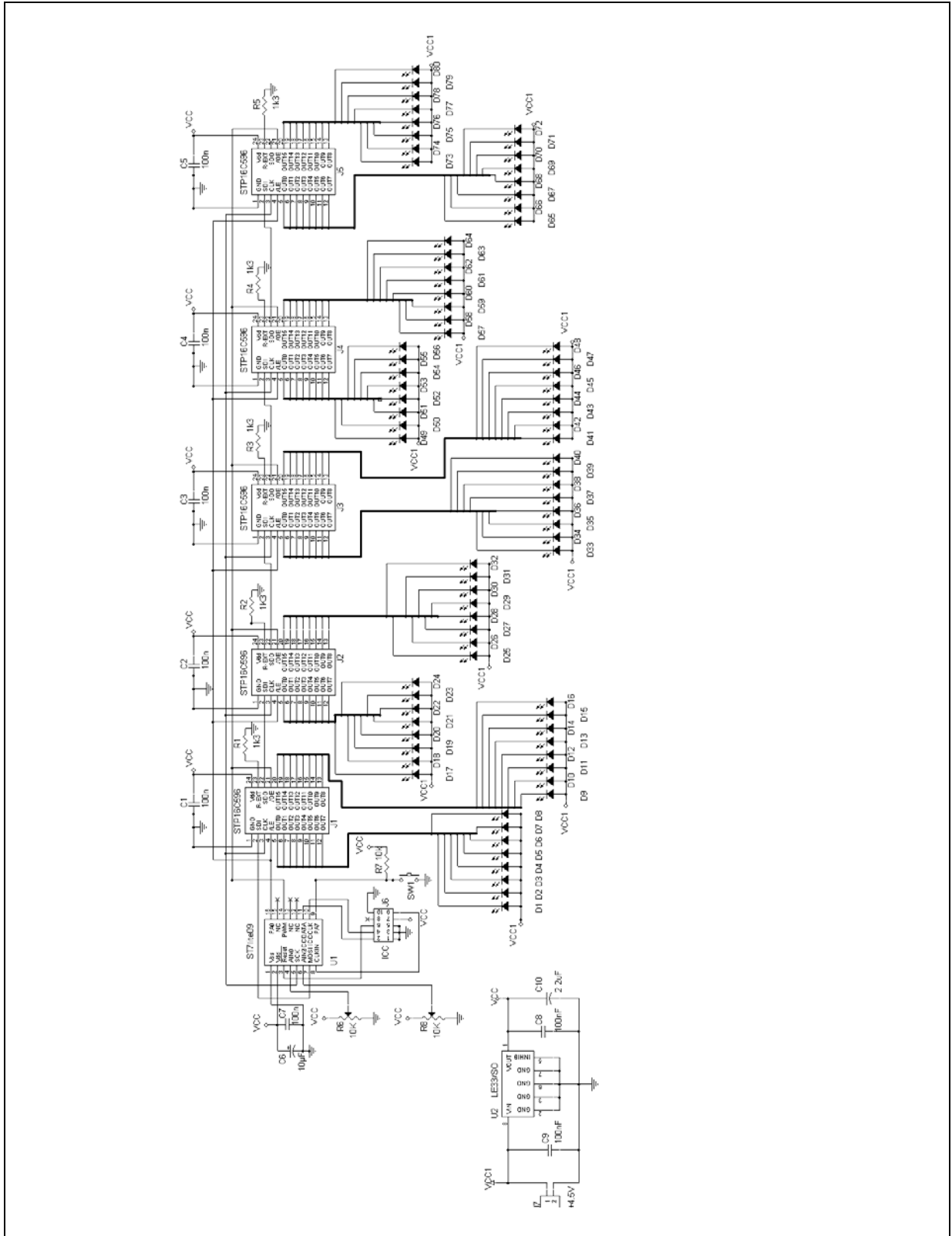
6.2 32LEDS ARRAY REFERENCE DESIGN

Figure 8. 32LEDs Array Reference Board

The 32LEDs array reference board is shown in the Figure 8 and its block schematic description is corresponding with section 2 BLOCK SCHEMATIC. All components are placed on the top side of the board. This board has a SMPS DC/DC converter using L5970D step down switching regulator for input voltages from 5 up to 35V. The ordering code for this reference board is:

STEVAL-ILL003V1
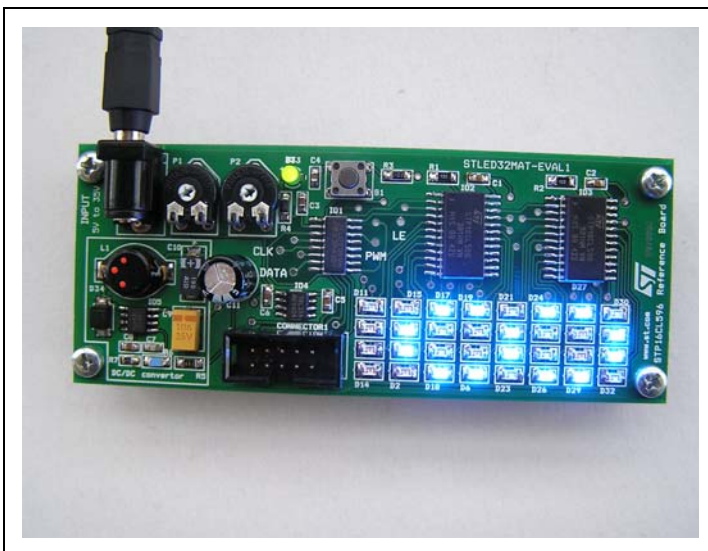
6.2.1 APPLICATION SCHEMATIC

The detailed application schematic of this design is shown in Figure 9. Two LED drivers STP16CP596 with 16 outputs each are controlled by one micro ST7LITE09. All principals and functions (communication, brightness regulation, blinking speed regulation) are similar to the 80LEDs array reference board. In addition there is the SMPS DC/DC converter. Its output voltage is 4V and its maximum current is 1A (L5970D device). For more design details of this converter, please refer to [3]. The clock frequency in this application is 83.6KHz and the PWM signal for brightness regulation is 654Hz.

Figure 9. Application Schematic
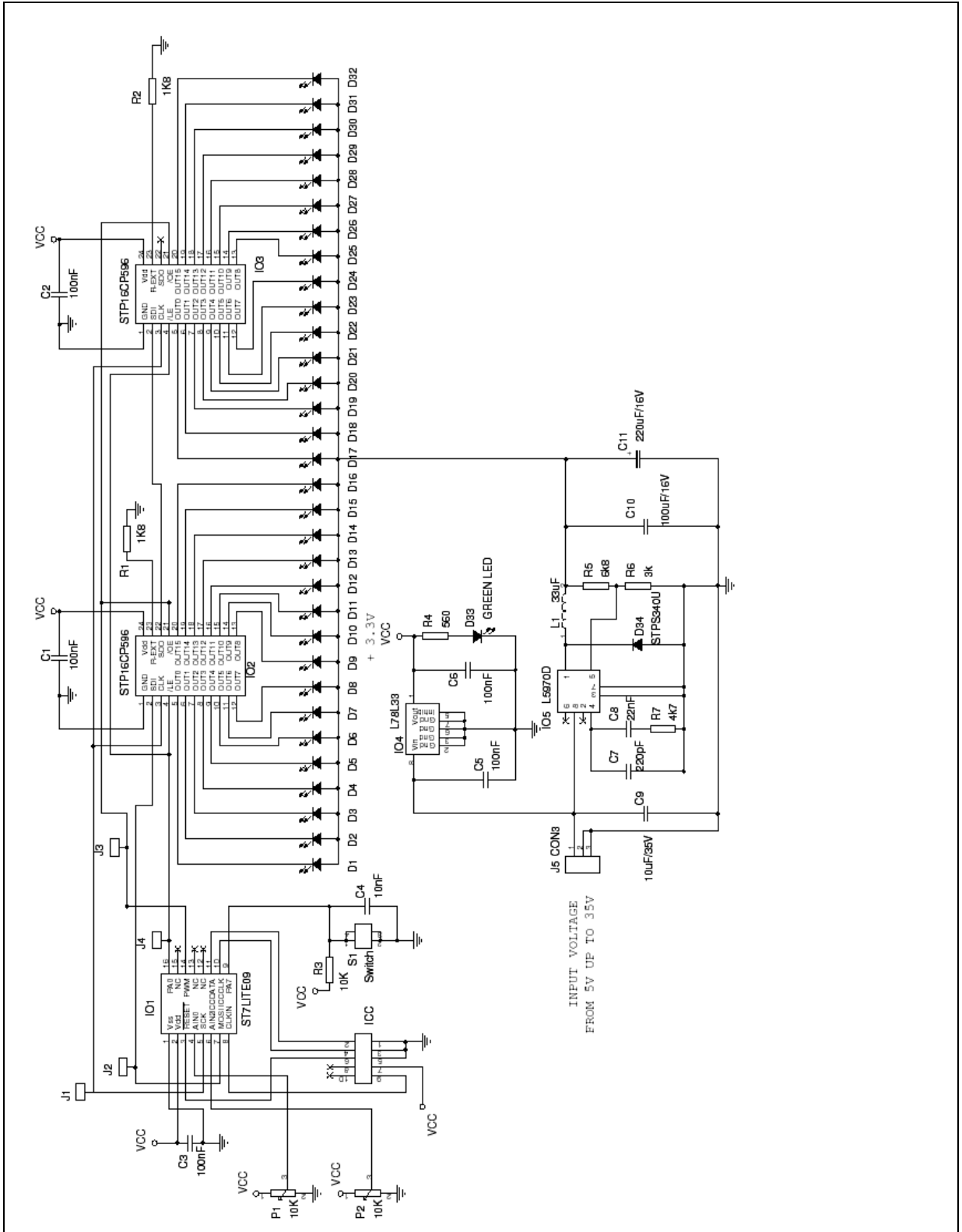
6.2.2 BOM

Item	Quantity	Reference	Part	Ordering code
1	1	CONNECTOR1	I_{CC}	
2	5	C1, C2, C3, C5, C6	100nF	
3	1	C4	10nF	
4	1	C7	220pF	
5	1	C8	22nF	
6	1	C9	10µF/35V	
7	1	C10	100µF/16V	
8	1	C11	220µF/16V	
9	32	D1 - D32	OSRAM SMD BLUE LED - LB T68C-P2S1-35	OSRAM - Q65110A1978
10	1	D33	SMD GREEN LED	
11	1	D34	STPS340U	STPS340U
12	1	IO1	ST7LITE09	ST7FLITE09Y0M6
13	2	IO2, IO3	STP16CP596	STP16CP596M
14	1	IO4	78L33	L78L33ACD
15	1	IO5	L5970D	L5970D
16	4	J1, J2, J3, J4	CON1	
17	1	J5	CON3	
18	1	L1	33µH	COILCRAFT - DO3316P-333
19	3	P1, P2, R3	10K	
20	2	R1, R2	1K8	
21	1	R4	560Ω	
22	1	R5	6k8	
23	1	R6	3k	
24	1	R7	4k7	
25	1	S1	Switch	

7 REFERENCES AND RELATED MATERIALS

[1] STP16CP596 and STP16CL596 datasheet

[2] ST7LITE0 datasheet

[3] L5970D datasheet

8 REVISION HISTORY

Date	Revision	Changes
28-Apr-2005	1	Initial release.
17-Nov-2005	2	Added information about new LED driver STP16CP596. Modified Table 6.2.2. and Figure 9.