NCV7685I2CV1GEVB

NCV7685 Twelve Channels LED Linear Current Driver with I²C Interface Evaluation Board User's Manual

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EVAL BOAR USER'S MANUAL

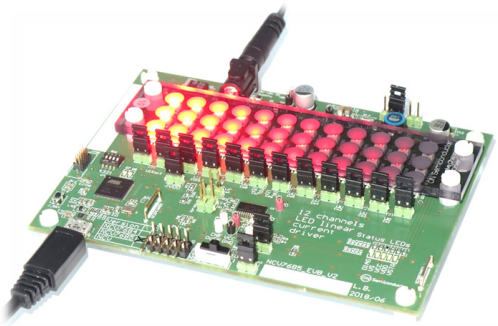

Figure 1. NCV7685I2CV1GEVB

Introduction

The evaluation board demonstrates the Rear Combination Lamp Application with the NCV7685 LED linear current driver. On-board buck converter creates constant voltage of 7.0 V on the top of the LEDs to have lower power dissipation on the device itself. The board contains up to three LEDs in a series for each twelve channels. The amber color of the LEDs emulates TAIL/STOP functionality. The board contain jumper switch where demonstration mode or evaluation mode can be selected. Several different animations can be played without need of computer connection in demonstration mode.

NCV7685 has several kinds of the fault detections. Fault detection can be emulated by shorting or opening on-board jumpers. The indication LEDs can inform users about diagnostic and the status of the supplies. More faults and statuses can be read out using PC control software in the evaluation mode configuration.

Multiple evaluation boards can be interconnected using I²C communication + DIAG interface. Because default address is the same for every board, the I²C address has to be set independently.

Evaluation Board Features

- Wide Range of Supply Voltage: 8 to 18 V
- 3 × 12 Amber LEDs
- V_{STRING} Voltage 7.0 V
- V_{DD} Voltage 5.0 V
- Nominal LED String Current
  - 10 mA – Nominal Current
  - 50 mA – High Current Set by Jumper
- Input CONF1 and CONF2 Switch Selector
- LED Open-loads, I_{SET} Short to Ground Emulation Jumpers
- Loss of V_{DD} and loss of VS Emulation Jumper
- Thermal Shutdown
- Global Output Enable Jumper
- External I²C Header Connector
- Positions for Optional EMC Capacitors
- Backward PCB Compatibility with the NCV7684 Device

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Table 1. ABSOLUTE MAXIMUM RATINGS

Rating	Value	Unit
Supply Voltage (V_{BAT})	−28 to +28	V
LED Strings Current	720	mA
Junction Temperature (NCV7685, NCV8853)	−40 to +150	°C
Junction Temperature (Advanced Power TOPLED OSRAM LED)	−40 to +125	°C
Ambient Temperature	−40 to +105	°C

Stresses exceeding those listed in the Maximum Ratings table may damage the device. If any of these limits are exceeded, device functionality should not be assumed, damage may occur and reliability may be affected.

Table 2. RECOMMENDED OPERATING CONDITIONS

Rating	Value	Unit
Supply Voltage (V_{BAT})	8 to 18	V
Rated LED String Current	10/50	mA
Fault Mode − Board Consumption (VS = 13.5 V, AutoR = 1, MCU disconnected, status LEDs powered)	≈9	mA
Auxiliary Circuits Consumption (DC/DC, LDO, MCU, pull-ups, …)	≈68	mA
Ambient Temperature (for rated LED current)	−40 to +105	°C

Functional operation above the stresses listed in the Recommended Operating Ranges is not implied. Extended exposure to stresses beyond the Recommended Operating Ranges limits may affect device reliability.

Table 3. INTERFACE FUNCTION DESCRIPTION

Connector Name	Connector Type	Description/Function
Supply	DC POWER, 2.1MM	Input supply connector, DC 8−18 V.
$J_{DCShort}$	1x2 Header	Bypass DC/DC converter, apply supply voltage to V_{STRING}.
J_{UV}	1x2 Header	Decrease V_{STRING} voltage from 7 V to 6 V.
J_{VS}	1x2 Header	VS supply to the NCV7685.
J_{VDD}	1x2 Header	VDD supply to the NCV7685.
J_{OEN}	1x2 Header	Disconnect J_{OEN} during startup. To deactivate all outputs, put OEN pin to low, otherwise keep OEN pin high during the normal operation.
J_{HiCur}	1x2 Header	10 mA/50 mA current setting.
OL1 − OL12	1x2 Header	Open Load emulation jumper.
$J_{prog/sh}$	2x2H Header	Emulate short of the I_{SET} pin. (Horizontal position)
$J_{prog/sh}$	2x2V Header	Apply 2.9 V on the I_{SET} pin (for OTP read/write access). (Vertical position)
I2Ca	1x5 Header	Digital supply, I^2C line and Diagnostic connector.
I2Cb	1x5RA Header	Digital supply, I^2C line and Diagnostic connector.
$J_{_JTAG}$	2x5 Header	JTAG programming connector for MCU.
SW1	Switch 4P	Demonstration Mode / Evaluation mode.
J_RST	Button	MCU reset button.
SW_{Conf}	Switch	CONF1/CONF2 selector.
VBAT, GN, EN, VDD, CNF, DgEN, VCC, PwG, GND, OEN, DIAG	Test Point	Test points.
ScopeGND1, ScopeGND2	Wire Bridge	Ground wire.
J_{USB}	microUSB	Micro USB − PC connector.
NT3	Jumper Strap	Powering resistor divider for 2.9 V supply for OTP access.
NT4	Jumper Strap	Enabling of DC/DC converter.
NT5	Jumper Strap	Powering digital supply for MCU.

Getting Started

The evaluation board is supplied through a standard 5.5 × 2.1 mm DC connector. Supply voltage range has to be from 8 to 18 V. Below 8 V the current through the LEDs starts decreasing. For the supply voltage above 18 V, the board temperature can be the limitation. Jumpers J_{VS}, J_{VDD} and J_{OEN} should be connected for normal operation.

The NCV7685 evaluation boards can work either in *Demonstration mode*, where animation is performed in the loop or in *Evaluation mode* where user can evaluate all functions using computer control program.

For the *Evaluation mode* the EVB board has to be connected to the PC and controlled using SW program. To activate the Evaluation mode the SW1[1] switch has to be configured that pin 1 is in OFF position, other pins doesn't care. Resetting the MCU using J_RST button is highly recommended before connection to the PC software. The Software description is in the Page 7.

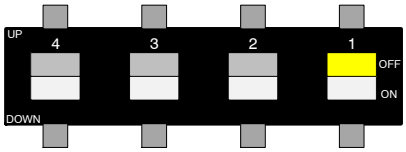


Figure 2. SW1 Configuration for Evaluation Mode

For the *Demonstration mode* the VS, VDD and Output ENable jumpers (J_{VS}, J_{VDD} and J_{OEN}) has to be closed. The MCU performs the animation effects in the loop in the standalone way without need of PC.

One of the eight different animation effects can be selected by SW1[4:2]. Activation of the Demonstration mode is done by switching SW1[1] to ON position.

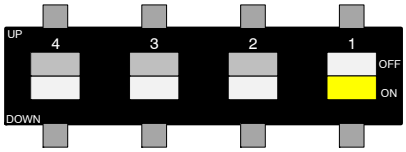


Figure 3. SW1 Configuration for Demonstration Mode

The status of the SWx switch is read at the end of each animation. If the animation has to be started from the beginning, or different mode has to be set during started animation, the reset button J_RST will change the mode immediately. The list of all animation is shown in Figure 4.

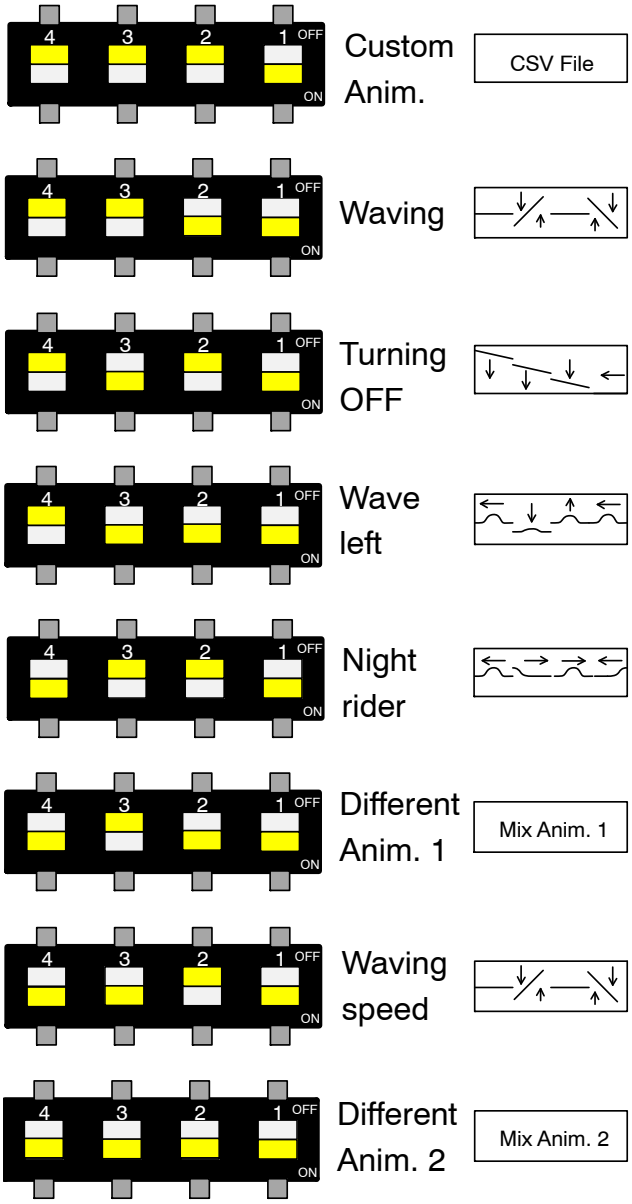


Figure 4. SW1 Configuration for Different Animation Selection

The LED current which is driven by NCV7685 can be changed replacing R1 and R2 resistors using following formula:

$$I_{OUTX} = \frac{K \cdot 1\,V}{R_{SET}} = \frac{100 \cdot 1}{2000} = 0.05\ [A] \qquad \text{(eq. 1)}$$

$$R_{SET} = R1 + R2\ [\Omega] \qquad \text{(eq. 2)}$$

Where:

I_{OUTx} – OUTx LED channel current flow
K – I_{SET} factor with value of 100
R_{SET} – Total I_{SET} Resistance
R1 – “Shielded” Resistor
R2 – “Adjustment” Resistor

The LED current flow is set to 10 mA per each activated channel by default. The current can be increased by shorting JHiCur header by jumper up to 50 mA per active channel.

To ensure stable low voltage drop on the output pins, using DC/DC converter is highly recommended. The V_{STRING} voltage is provided by buck DC/DC converter which is configured to have output voltage at 7.0 V. If needed the V_{STRING} voltage can be adjusted by replacing the R_A and R_B resistors.

The formula for V_{STRING} voltage using NCV8853 converter is:

$$V_{STRING} = 0.8 \cdot \frac{R_A + R_B}{R_B} \qquad \text{(eq. 3)}$$

The DC/DC converter can be easily bypassed by shorting jumper $J_{DCshort}$. After bypassing the DC/DC converter, the V_{STRING} voltage will be powered directly from the V_{BAT}. Applying too high V_{BAT} voltage with combination with high current setting can cause high thermal dissipation and device will go into thermal shutdown mode.

Shorting under voltage jumper J_{UV} can emulate under voltage on the top of the LEDs (V_{STRING}) which will be 1.0 V less then nominal. During the under voltage the output voltage of the DIAGEN resistor divider will be below threshold and this can be detected by the NCV7685 device. This will lead to disable diagnostic detection. The DIAGEN status flag can be read in I^2C mode.

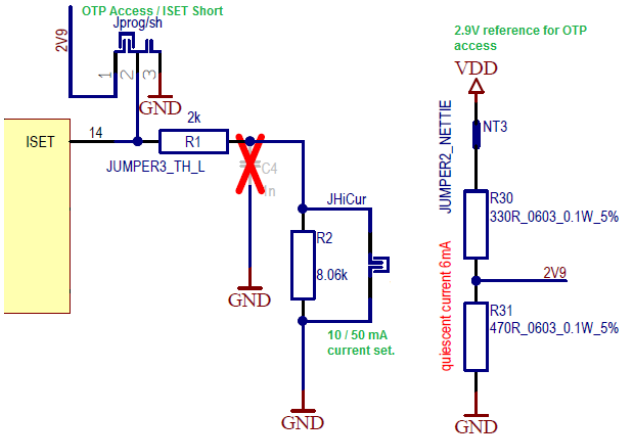


Figure 5. Schematic of the I_{SET} Connection

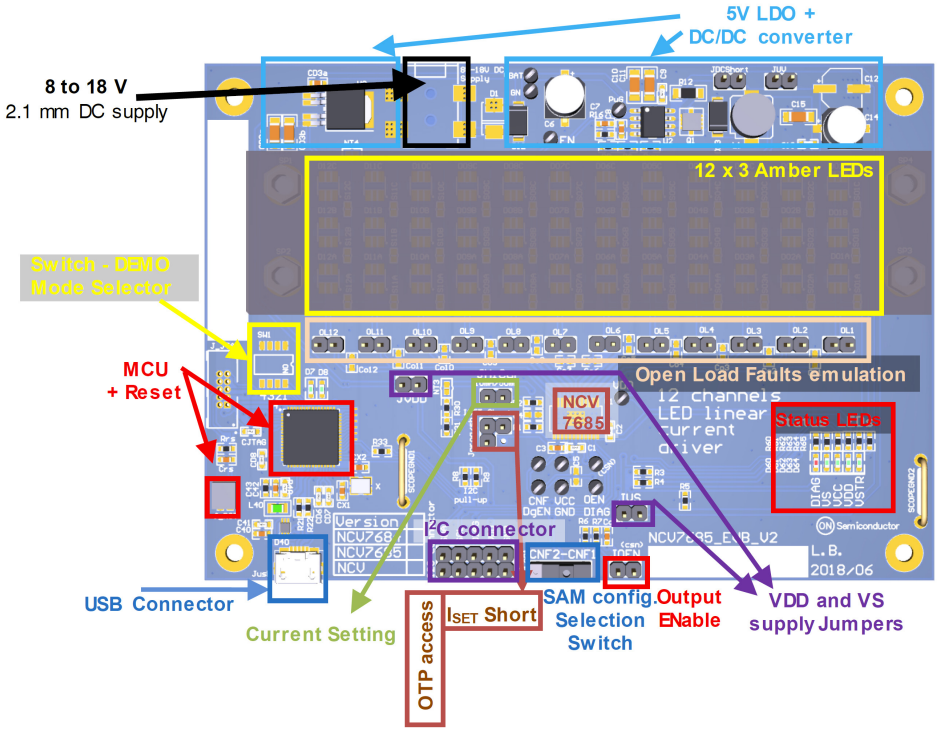
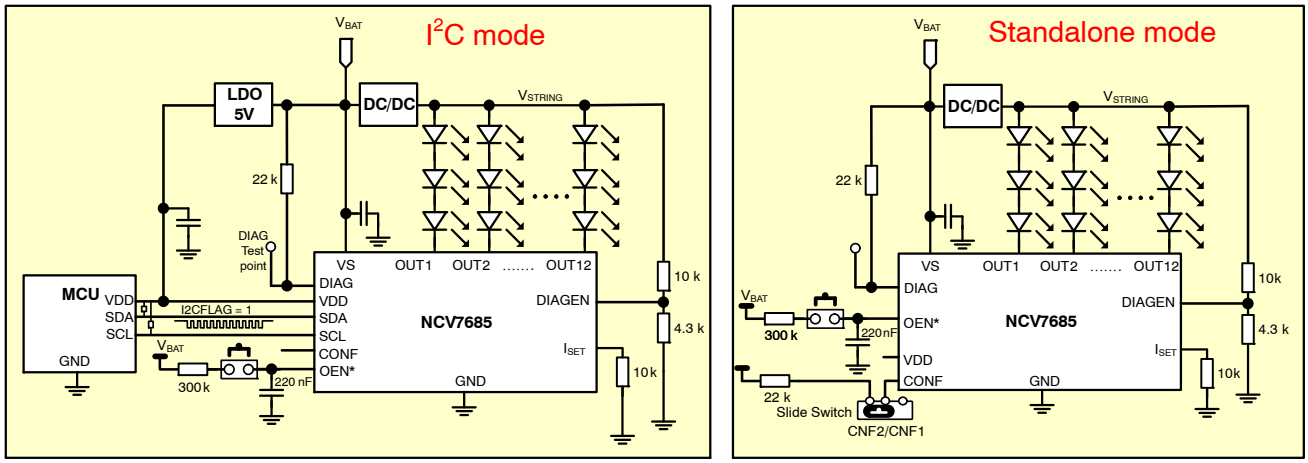


Figure 6. NCV7685 Twelve Channel LED Linear Current Driver Board Picture

Modules Control Strategy

The board is designed to operate primary with DC/DC converter which creates stable voltage on the V_{STRING} supply line. The high voltage drop on the OUTx pins in combination with higher currents can cause huge power dissipation. To have reasonable power dissipation, the voltage on the OUTx pin in ON state should be limited to max 1.0 V during high current flow. Forward voltage of the LEDs depends on the number of connected LED string can be from 2.0 V to 6.0 V. The NCV7685 can operate in I²C or in standalone mode.



NOTE: *The OEN voltage has to be lower than 5 mV/10 μs during the startup according to the application note AND90032/D [4] otherwise wrong startup may occur.
It is necessary to power−up the board with J_{OEN} jumper disconnected, or to carefully verify the voltage on the OEN pin during the startup. Some of the EVB boards may be still assembled with lower RC filter, please review the R7 and Coen value before using this EVB board. If voltage on the OEN pin is not lower than 5 mV/10 μs, then the R7 has to be changed from original 22 kΩ to 300 kΩ and Coen from original 1 nF to 220 nF.

Figure 7. Simplified Options How to Control Current Flow by the LEDs

Standalone Mode

Device enters into standalone mode in following cases:

- Immediately after startup
- When V_{DD} voltage falls down below undervoltage threshold
- When I2CFLAG is cleared down

The output channel configuration and diagnostic behavior is read out from OTPs. Two possible output channel configurations can be set, depending on the CONF pin setting. The output channels can be either turned ON or OFF.

I²C Mode

To enter into I²C mode the V_{DD} supply is needed. Device will enter into I²C mode as soon as the I2CFLAG is set.

Extended functions can be controlled or read in I²C mode:

- PWM control
- OTP programming
- Diagnostic control
- ON/OFF activation of the individual channels
- Reading status bits
- Reading extended Fault statuses

How to control the I²C registers is described in the NCV7685 datasheet or in the NCV7685 I²C Programming Guide application note.

I_{SET} Capability

The output current of the active channels is defined by external resistor between I_{SET} and ground.

The default configuration of the I_{SET} connection is descripted in Figure 5. If the EMC improvement is needed, the simple modification with external C4 capacitor can be applied.

Horizontal jumper connection Jprog/sh can emulate short I_{SET} to ground. During normal operation this jumper is in open position.

The output LED current setting can be changed by shorting/opening jumper JHiCur. When the jumper JHiCur is open, the output current is only 10 mA per channel. Increase output current can be achieved by shorting the terminals. The current can be increased up to 50 mA per one channel.

The access to the OTP registers is allowed only when voltage between 2.5 V and 3.3 V is applied to the I_{SET} pin. The resistor divider R30 and R31 creates 2.9 V voltage which can be applied to the I_{SET} pin by vertical jumper connection of the Jprog/sh header. The closing position for OTP programming is shown in Figure 8.

Power Dissipation

The main source of power dissipation is device itself and the on board LEDs. Total power dissipation of all 36 Red LEDs which are operated at 50 mA is 3.37 W.

The thermal resistance of the SSOP24 package with expose pad mounted on this evaluation board is around 42.6°C/W. The thermal shutdown was achieved at ambient temperature when OUTx voltage was higher than 5.87 V for 50 mA per each output. Maximum power dissipation on the linear driver which can NCV7685 EVB board handle is 3.52 W at ambient temperature. Using DC/DC converter with voltage drop of 1.0 V on the activated outputs will decrease the power dissipation on the linear driver significantly.

Thermal warning flag is activated with junction temperature above 140°C.

The formula to calculate thermal heating is following:

$$\Delta T_J = R_{\theta JA} \cdot P\ [°C]$$

$$\Delta T_J = 42.6 \cdot 0.8°C \qquad \text{(eq. 4)}$$

$$\Delta T_J = 34.1°C$$

The junction temperature will raise about 34.1°C above ambient temperature when the overall power dissipation on the device will be 0.8 W.

The worst case power dissipation is calculated as:

$$P = N \cdot V_{OUTx} \cdot I_{OUTx} + V_{BATMax} \cdot I_{VS} + I_{VCC} \cdot (V_{BATMax} - V_{CC})$$

$$P = 12 \cdot 1.0 \cdot 0.05 + 18.0 \cdot 0.01 + 0.001 \cdot (18.0 - 3.3)$$

$$P = 0.8\ W \qquad \text{(eq. 5)}$$

Where:

- ΔT_J – Increase temperature of the device
- $R_{\theta JA}$ – Thermal resistance Junction – Ambient
- P – Power dissipation of the NCV7685
- V_{OUTx} – Voltage drop on the OUTx pin
- I_{OUTx} – LED Output current
- N – Number of channels
- V_{BATMax} – Maximum battery voltage
- I_{VS} – NCV7685 device current consumption
- V_{CC} – Output reference voltage
- I_{VCC} – Output reference current

Diagnostic and Fault Detection

The NCV7685 can detect several status flags and faults. The faults may be reported to the DIAG pin and reported into registers. Open Load diagnostic is enabled only if DIAGEN voltage is higher than DIAGEN enable threshold (2.0 V typ.) simultaneously the diagnostic bits have to be appropriate configured. In case of slow ramp-up of the V_{STRING} voltage the diagnostic is disabled to not report false open loads using the DIAGEN circuitry. Other faults and statuses are reported in the I2C_STATUS register. How a fault is reported and processed depends on the configuration of the OTP or I^2C Registers in combination with DIAGEN signal.

Setting the *AutoR (I2CAutoR) bit* will cause switching OFF all channels when at least one fault is present. Open Drain DIAG signal is pulled low to indicate the fault. If external fault is present, DIAG pin is pulled low externally, it will lead to switching OFF all channels. As soon as the fault is recovered, the LED driver returns to normal operation.

If *DetOnly (I2CDOnly) is set,* Open Load diagnostic is performed. When a fault is detected, the DIAG pin is set without taking any action on the current regulation. If Diag pin is pulled low externally, there is no action on the current regulation. The status of the Open Loads can be read in the I^2C registers.

In case of *none of the bits are set,* no Open Load diagnostic is performed and reported neither in I^2C register nor on the DIAG pin.

If *both flag bits* (AutoR and DetOnly) are set, the previous setting register is taken into account.

DIAGEN voltage is sensing via 10 kΩ and 4.3 kΩ resistor divider the V_{STRING} voltage. During the normal operation while V_{STRING} = 7.0 V, the typical voltage on the DIAG pin is 2.105 V which is above the threshold. If the voltage on V_{STRING} drops down, the diagnostic will be disabled.

Under voltage on the V_{STRING} can be emulated by shorting J_{UV} jumper. It will lead to decrease V_{STRING} to 6.0 V. The DIAGEN voltage will be below the threshold with value 1.8 V. The voltage status can be verified by reading the status register.

Table 4. FAULTS BEHAVIOR IN CASE OF OPEN LOAD ON SOME CHANNELS (OL), EXTERNAL DIAG ERROR, OR I_{SET} SHORT

AutoR or (I2CautoR)	DetOnly or (I2CdOnly)	DIAGEN	Fault Type	Remaining LEDs during the Error	DIAG Pin	DIAG err FLAG	OL FLAG	SC FLAG
0	0	> 2 V	OL	ON	not active	0	0	0
0	1	> 2 V	OL	ON	Fault	0	1	0
1	0	> 2 V	OL	OFF	Fault	0	1	0
1	1	> 2 V	OL	previous setting	prev. set	0	prev. set	0
x	x	< 2 V	OL	ON	not active	0	?(*)	0
x	x	< 2 V	DIAG err	ON	External	1	0	0
0	0	> 2 V	DIAG err	ON	External	1	0	0
0	1	> 2 V	DIAG err	ON	External	1	0	0
1	0	> 2 V	DIAG err	OFF	External	1	0	0
1	1	> 2 V	DIAG err	previous setting	External	1	0	0
x	x	x	I_{SET} short	OFF	Fault	0	0	1
?(*) NCV7685 maintain its last value								

PC Control Software

On-board *Microcontroller* together with PC software allows control the NCV7685 device using I^2C bus. All statuses can be read and they are easily visible in the control panel. (Figure 9). The register names and individual bits in the control panel correspond to the registers which are described in the datasheet. Every register can be read or write by appropriate button. Please note that for access to *Hard Coding Registers* and OTP registers the I_{SET} pin has to be put in range of 2.5 V ≤ I_{SET} ≤ 3.3 V. Figure 8 show where to connect jumper to apply 2.9 V on the I_{SET} pin.

The evaluation board can be also controlled by sending specific commands to MCU using serial port terminal program.

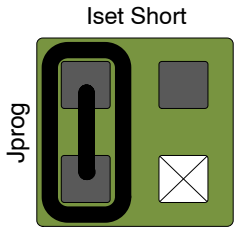


Figure 8. I_{SET} Jumper Connection to Have Access to the OTP and Hard Coding Registers

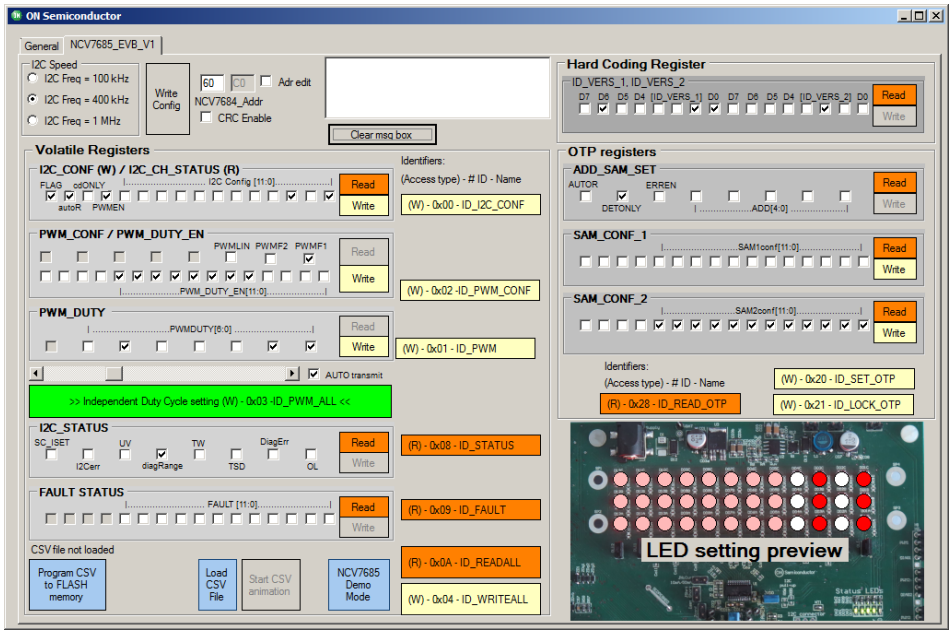


Figure 9. PC Control Panel for NCV7685_EVB_V1

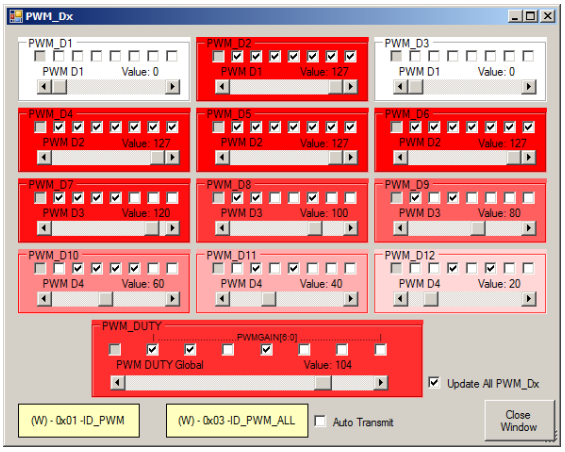


Figure 10. Individual PWM Duty Cycle Setting

PC Control Software Getting Started

1. Disconnect all jumpers except J_{VS} and J_{VDD}.
2. Set first pin of the SW1 switch to the OFF position (Figure 2).
3. Supply the board using 12 V, 1 A power supply.
4. Connect J_{OEN} jumper.
5. Connect the EVB board and PC using micro USB cable by J_{USB} connector.
6. Push J_RST reset button for 1 s.
7. Install USB drivers and PC software. (only for first time)
8. Open NCV7685_EVB_V1 PC SW.
9. Click on "*Update Port List*".
10. Choose appropriate COM port. (If there are already multiple COM ports available, then disconnect the USB cable, check the available COM ports then connect USB cable and the new COM port belongs to the NCV7685_EVB_V1 board.)
11. Click on the "*Open Port*".
12. The connection can be verified by clicking on the "*Get Version*" button where MCU should response the actual FW version similarly as follows:

```
tx> get ver
rx> ver=NCV7685_rev_1 2018-03-05
```

13. In the "*NCV7685_EVB_V1*" tab the MCU has to be configured for I^2C functionality by clicking on the "*Write Config*" button.
14. The response from the MCU should be following:

```
tx> set I2C1CONF
tx> set I2C1SPEED=1
rx> I2C1CONF:ok
rx> I2C1SPEED:ok
```

15. To check the functionality, set the registers based on the Figure 11 screenshot. Then click on the "write" buttons: *ID_I2C_CONF*, *ID_PWM_CONF* and *ID_PWM*. The expected output LED intensity is shown in Figure 12.

The Features of the PC Control Software

Independent Duty Cycle Setting

All PWM_Dx registers can be shown in the separate window by clicking on the "*>> Independent Duty Cycle setting <<*" button. If the "*Auto Transmit*" check box is set, every change of the scroll bars or the registers bits related to the duty cycle registers will be automatically transmitted.

Animation Demo Mode

The "*Automatic Demo ON*" button will configure the NCV7685 device for the PWM mode and it will start periodically sending the ID_PMW_ALL messages with the defined animation with time delay ≈ 50 ms between the messages. The NCV7685 device has to have 0x60 I^2C address. The animation can be interrupted by clicking on the "*Automatic Demo OFF*" button.

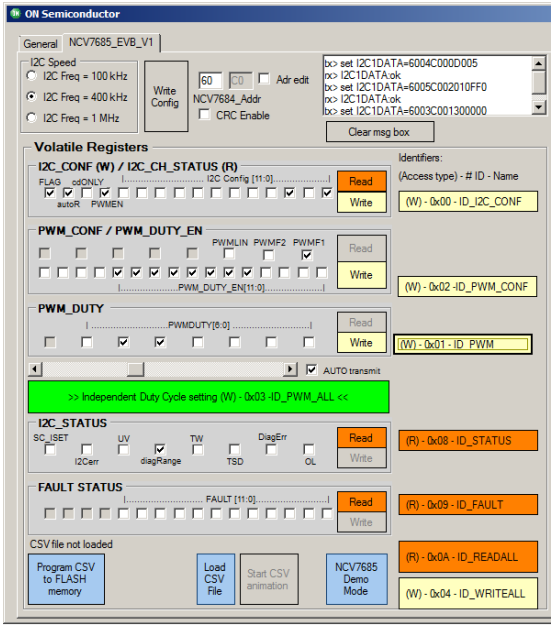


Figure 11. Test Register Setup

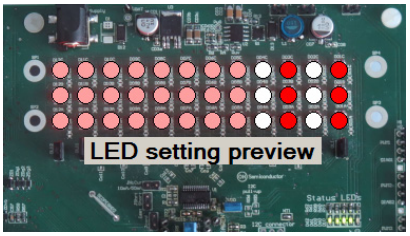


Figure 12. Expected Output Channel Intensity

Output LED Setting Preview

The result of the register setting and the influence on the output LEDs can be displayed in the picture in the right bottom corner. Please note that not all aspects are taken into account like external events, the CONF or OEN configuration. Also the Linear or Logarithmic translation effects are not considered to be shown.

Custom Animation

The custom animation can be created using the Animation_script_generator_NCV7685.xlsm.

The CSV output file can be either loaded and performed or flashed into FLASH memory of the MCU. The "*Load CSV*" button load the information about the CSV file and "*Start CSV Animation*" button will start periodically sending the ID_PWM_ALL messages with the CSV information. Please note that the timing is limited by UART communication speed.

To ensure exact timing, the animation has to be stored inside of the MCU using "*Program CSV to FLASH memory*" button. It can take longer to program huge CSV files.

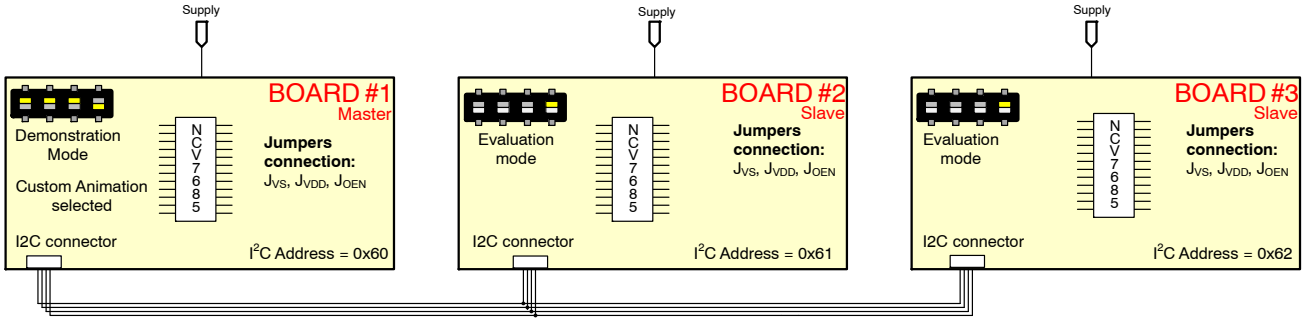


Figure 13. Connecting Multiple Modules into Parallel

Using Multiple Boards Connected into Parallel

Multiple NCV7685 evaluation boards can be connected into parallel using I^2C connector which contains I^2C lines, VDD supply and DIAG signal. The modules should be configured to the new I^2C address first. How to set new I^2C address is described in the application note [3].

Daisy chain connection can be used also in Demonstration mode using custom animation. Master board which is configured in Demonstration mode will control remaining modules which are configured in Evaluation mode.

NCV7684 Device Compatibility

The NCV7684 is almost pin to pin compatible with the NCV7685. The board is designed to be used with both silicon versions without need changing of any external component. Because NCV7684 is using for OTP access the CSN pin instead of I_{SET} the NT3 strap can be disconnected do decrease the power dissipation on the resistor divider. The J_{OEN} jumper will take over the CSN functionality. To activate OTP access, the J_{OEN} (CSN) jumper has to be connected.

The advanced animations are not possible in the demonstration mode with original NCV7685 MCU firmware. In case of using dedicated NCV7684 MCU firmware, the basic animation can be performed.

I^2C Communication Protocol Using Embedded MCU

Communication between MCU and PC is done via simple ASCII commands protocol. The commands how to control I^2C module, are shown in the Table 5.

Example of the setting FLAG in the I2C_CONF register:

set I2C1CONF	// I²C module configuration initialization
set I2C1SPEED=1	// 400 kHz speed
set I2C1DATA=6004C000BFFF	// Send over I²C four bytes with 0x60 address. Number of transmitted data = 0x04, Second address = 0xC0 (=RoL(0x60)+WriteFlag), ID = 0x00, I2C_CONF = 0x0BFF data.
set I2C1DATA=6007C004D000010FFF	// Send over I²C seven bytes with 0x60 address. The second address is shifted to the left and corresponds to the 0xC0. Identifier of the message is 0x04 (ID_WRITEALL).I2C_CONF is 0xD000. PWM_CONF is 0x01. The PWM_DUTY_EN is the 0x0FFF.

Read via I²C:

get I2C1DATAwr=600205C00A	// with address 0x60 write 0x02 bytes and read 0x05 bytes. The first transmitted byte is the second part address the 0xC0, the second transmitted byte is identifier for (ID_READALL = 0x0A).

Response:

I2C1DATAwr=05bfff110400	// received 0x05 bytes. 0xBFFF is I2C_CH_STATUS register. I2C_STATUS = 0x11 (DiagRange = 1 and Open Load = 1). FAULT_STATUS = 0x0400. (Eleventh channel is in Open Load condition)

NOTE: Every command has to be confirmed with <cr> character.

Table 5. THE I2C COMMUNICATION PROTOCOL USED BETWEEN MICORCONTROLLER AND PC

I²C		
	x – is a I²C Number 1 or 2	**X = 1**
Configuration	TX: set I2C{x}CONF<cr> RX: I2C{x}CONF:ok<cr> CONF – configures the I²C pins for I²C functionality and initialize I²C peripherial e.g. set I2C1CONF	–
Set I²C Speed	TX: set I2C{x}SPEED={speed}<cr> RX: I2C{x}SPEED:ok<cr> speed – 0 = 100 kHz; 1 = 400 kHz; 2 = 1 MHz e.g. set I2C2SPEED=1	100 kHz
Data Read/Write	Write TX: set I2C{x}DATA={addr}{count}{data}<cr> RX: I2C{x}DATA:ok<cr> addr – 7 bits device address count – number of data bytes data – is a byte array. Bytes are send from first to last. MSB is written first. e.g. set I2C1DATA=500212AB Read TX: get I2C{x}DATA={addr}{count}<cr> RX: I2C{x}DATA={count}{data}<cr> addr – 7 bits device address count – number of data bytes data – is a byte array. Bytes are send from first to last. MSB is written first. e.g. get I2C2DATA=5002 Write/Read with Repeated Start (Sr) TX: get I2C{x}DATAWR={addr}{count_write} {count_read}{data_write}<cr> RX: I2C{x}DATA={count}{data}<cr> addr – 7 bits device address count – number of data bytes data – is a byte array. Bytes are send from first to last. MSB is written first. e.g. get I2C1DATAWR=50020112AB (returns one data byte)	–

EVALUATION BOARD SCHEMATIC

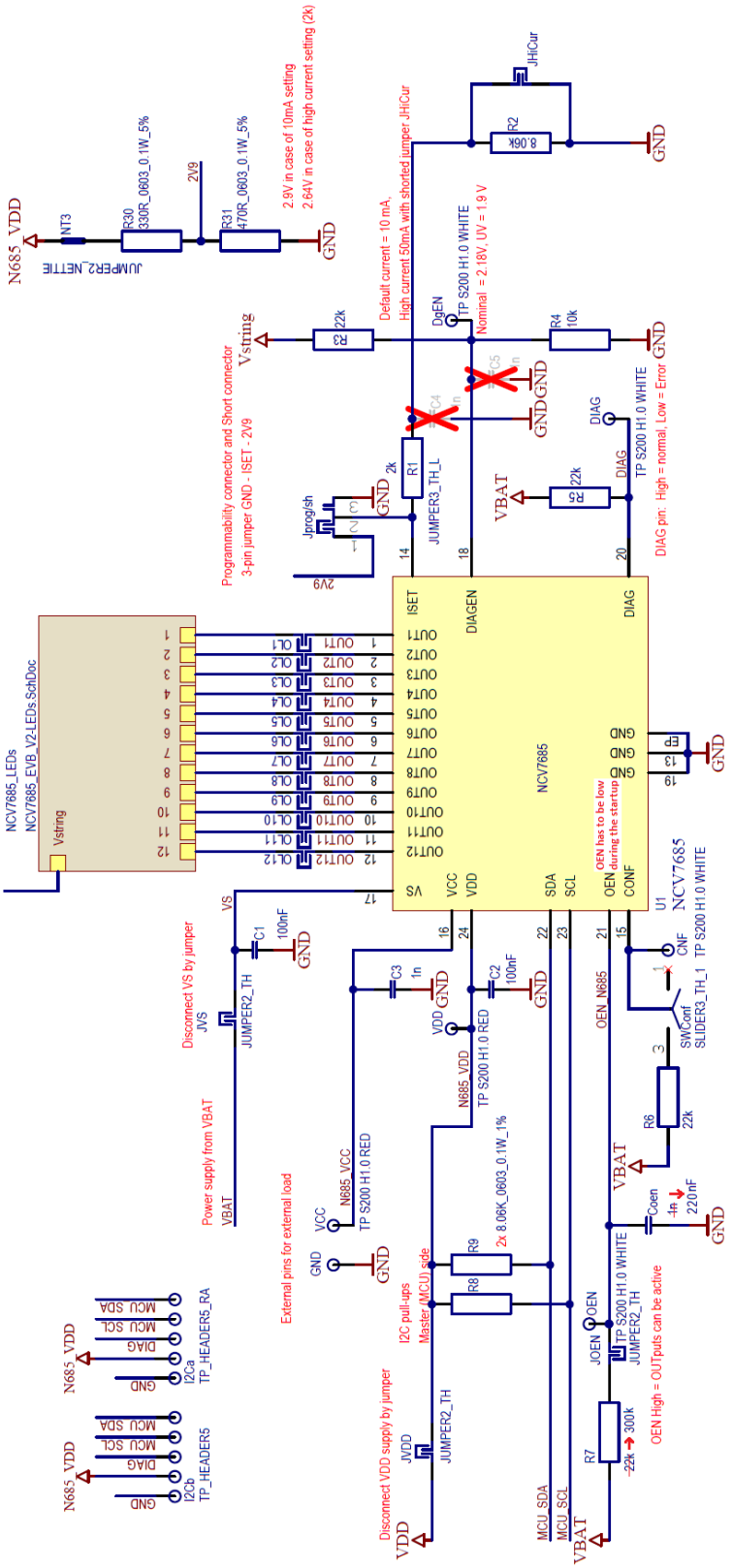


Figure 14. Schematic of the NCV7685 Device Block

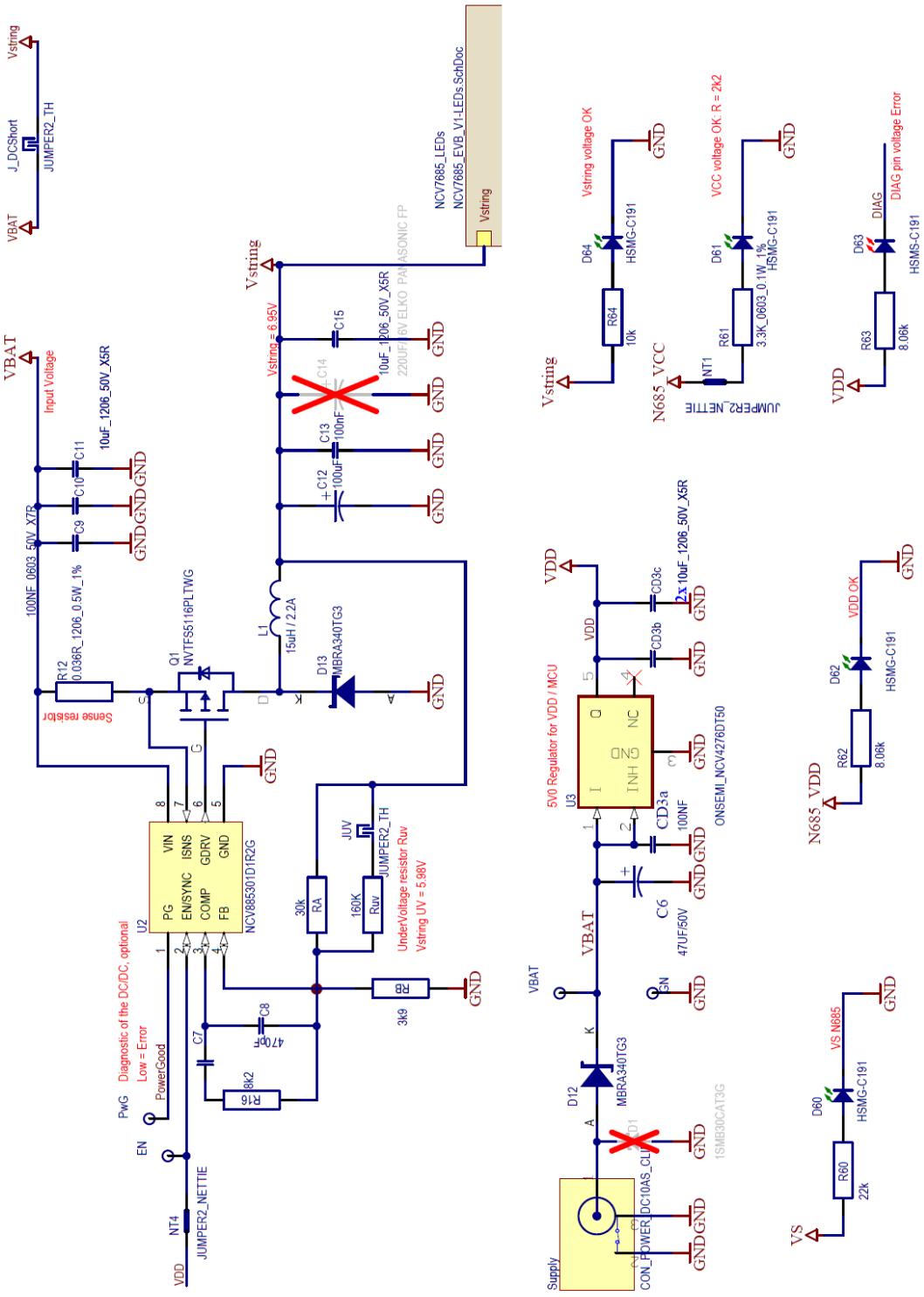


Figure 15. Schematic of the Supply Elements

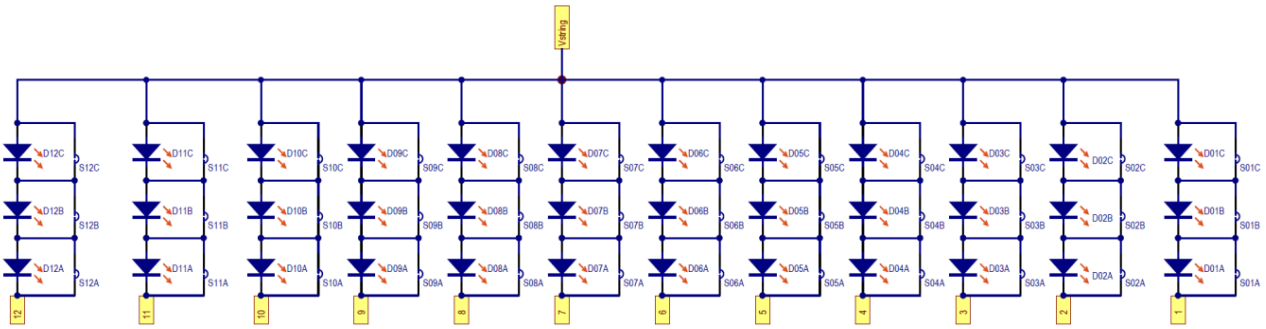


Figure 16. Schematic of the LEDs

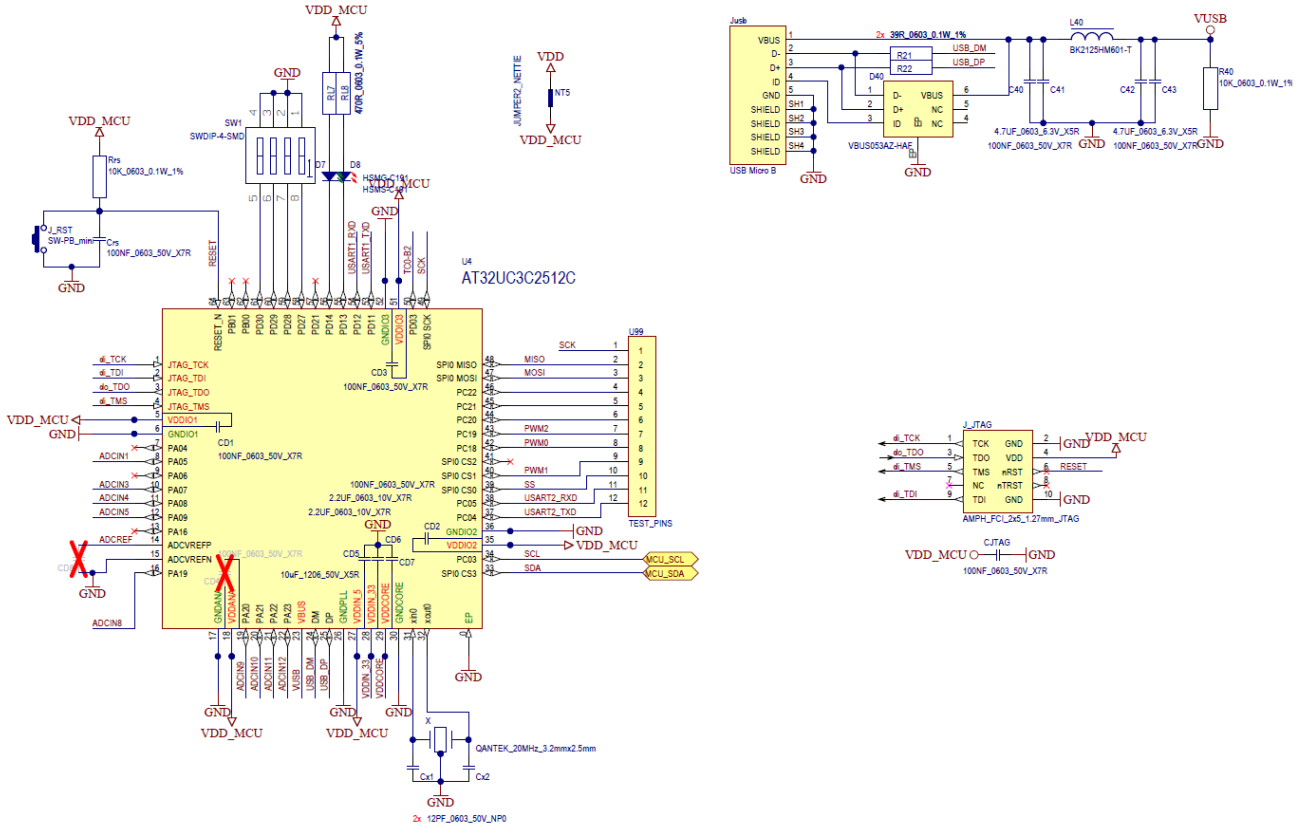


Figure 17. Schematic of the MCU

PCB DRAWINGS – ASSEMBLY

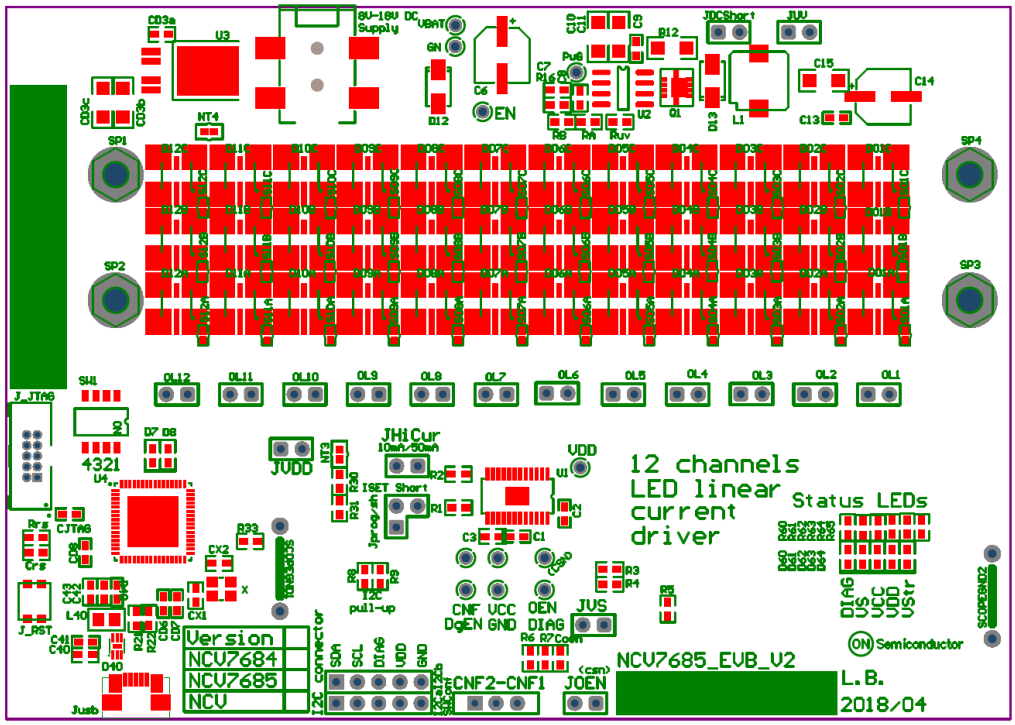


Figure 18. NCV7685 EVB PCB Top Assembly Drawing

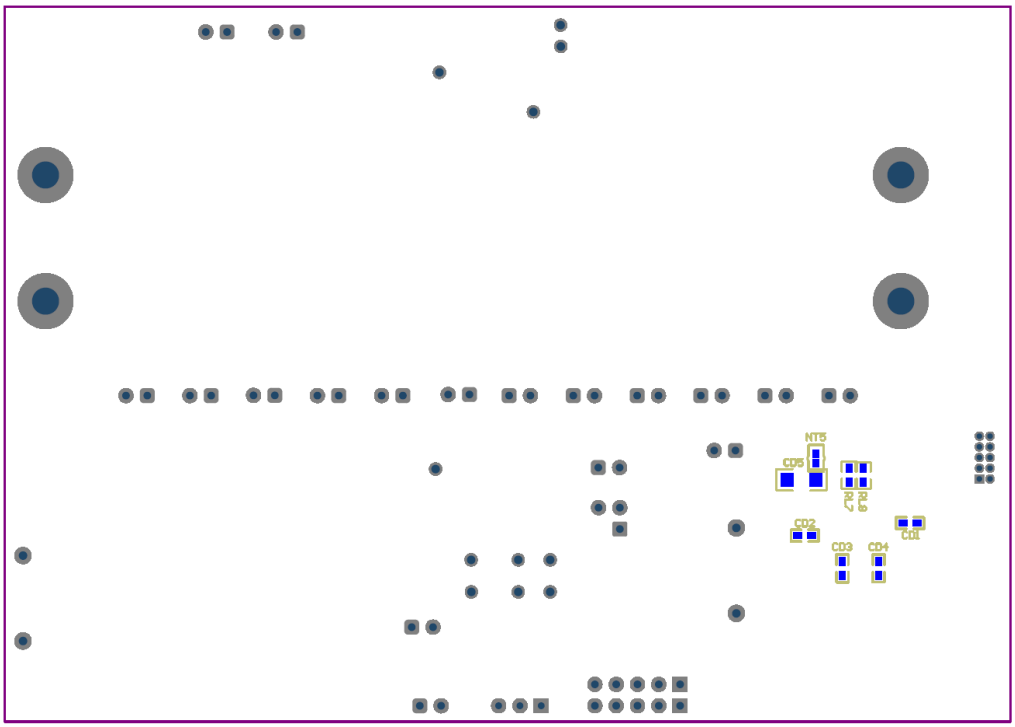


Figure 19. NCV7685 EVB PCB Bottom Assembly Drawing

PCB DRAWING – COMPOSITE

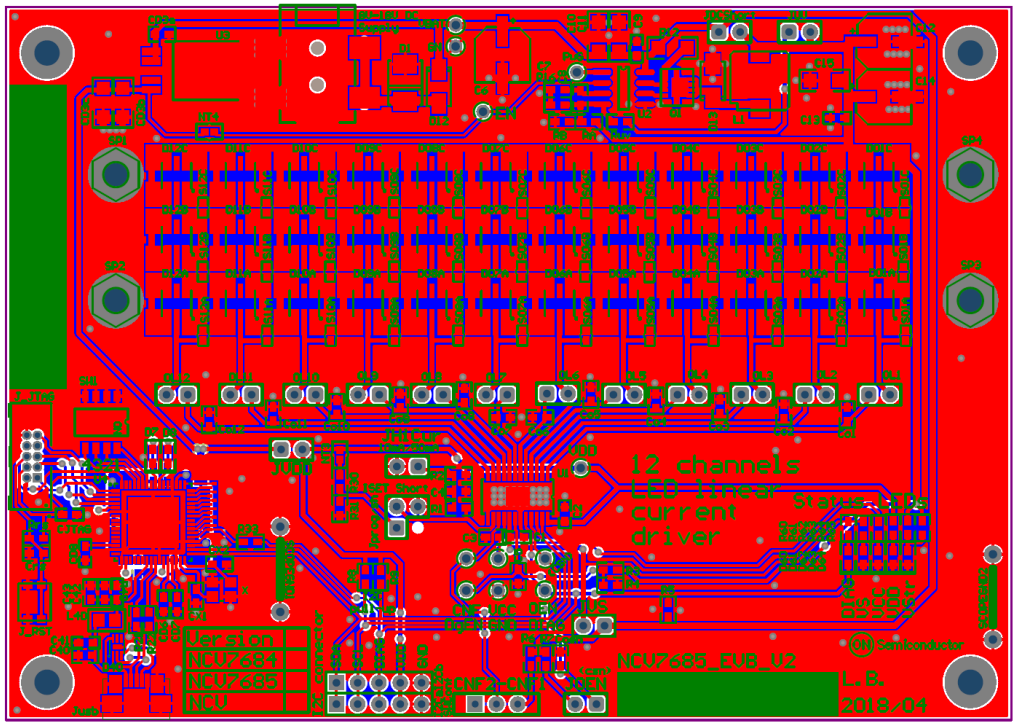


Figure 20. NCV7685 EVB PCB Top Composite Drawing

PCB PREVIEW

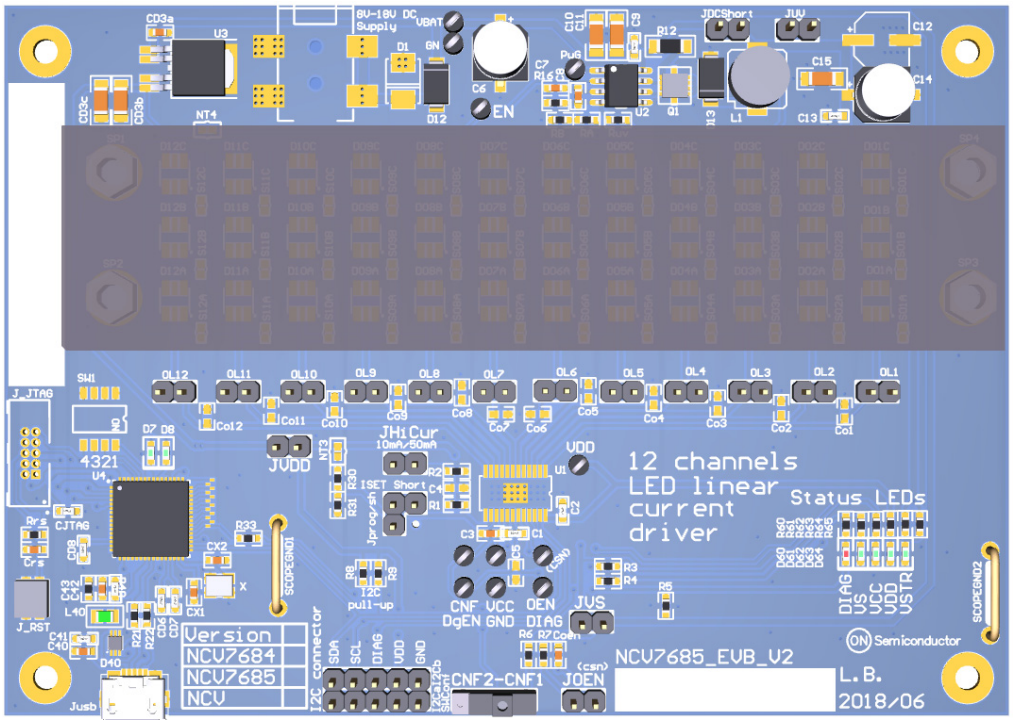


Figure 21. NCV7685 EVB PCB Top Side View

References

[1] ON Semiconductor, NCV7685/D: 12 Channels 60 mA LED Linear Current Driver I^{2}C Controllable for Automotive Applications, February, 2020 − Rev.1.
[2] ON Semiconductor, NCV8853/D: Automotive Grade Non-Synchronous Buck Controller, October, 2016 − Rev. 5.
[3] ON Semiconductor, AND9764/D: NCV7685 I^{2}C Programming Guide, May, 2020 – Rev.2.
[4] ON Semiconductor, AND90032/D: NCV7685 Driving of the OEN Pin During the VS Startup, March. 2020 − Rev. 0.

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