NCN5100 Arduino™ Shield Evaluation Board User's Manual

EVBUM2715/D

ON Semiconductor®

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EVAL BOARD USER'S MANUAL

INTRODUCTION

KNX [3] is a popular open home and building automation standard[1]. ON Semiconductor has a series of transceivers that handle the low level communication.

The NCN5100ASGEVB evaluation boards are Arduino-compatible shields enabling rapid prototyping with a microcontroller of choice. All external components necessary for operating the transceivers are present on the shield. Plug it in a Arduino-compatible development kit and start developing!

FEATURES

- Arduino Uno V3 compatible connectors
  - Compatible with a wide variety of microcontroller development boards
- Four on-board buttons/LEDs to build a dimmer application
- Available in UART- and SPI-version
  - Fully KNX-compliant transceiver
- Easily get started with KNX
- Maximum bus current up to 40 mA[2]
- Two high-efficiency DC-DC converters
  - 3.3 V fixed output
  - 1.2 V to 21 V variable output
- Integrated 20 V linear regulator output

OVERVIEW

The NCN5100ASGEVB boards come in three variants containing the NCN5110, NCN5121 and NCN5130 transceivers. The NCN5110 is a bit transceiver and all the timings are handled by the microcontroller. Both the NCN5121 and NCN5130 also implement the MAC layer, reducing the software development effort. All critical timings are handled by the transceiver.

All transceivers include two high-effciency DC-DC converters. One fixed converter generating 3.3 V, supplies the transceiver and other optional peripherals such as a microcontroller. The second DC-DC converter has an adjustable output voltage ranging from 1.2 V to 21 V and can be used to supply peripherals such as, relays, a display, etc. ...

The Arduino shield form factor makes it easy to start developing; just plug the shield into a compatible microcontroller board and start coding. Thanks to the on-board buttons and LEDs, it is not necessary to plug in additional shields to start testing. A simple dimmer application can be set-up in no time with only the KNX Arduino-shield.

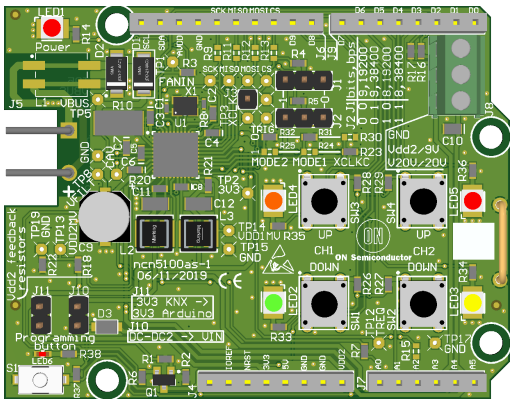

Figure 1. NCN5100AS-1 Evaluation Board

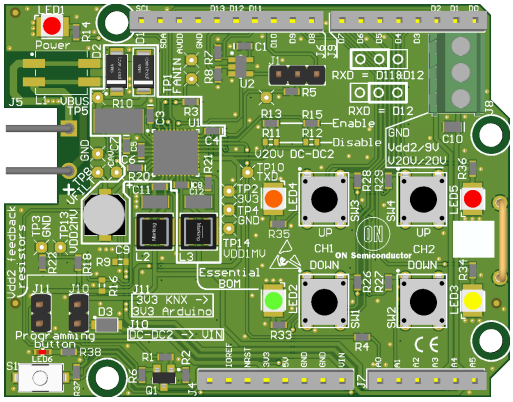

Figure 2. NCN5100AS-2 Evaluation Board

1 https://my.knx.org

2 For the NCN5130 and NCN5110 version. The NCN5121 goes up to 24 mA.

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Both the NCN5121 and NCN5130 come with an SPI and UART communication interface. The latter is fully TP-UART compatible, enabling the use of existing compatible software.

The boards are 2 layer PCB's with single-sided assembly, demonstrating that it is possible to easily develop low-cost applications.

EVALUATION BOARD OVERVIEW

The main connectivity to the evaluation board is provided through the Arduino V3 headers which can be seen in Figure 1. This has the advantage that the board is compatible with a wide variety of microcontroller development boards. Refer to Appendix C, Table 6 for a list of tested platforms.

The KNX-Bus

The KNX-bus consists of a twisted pair cable providing both data and power. The voltage on the bus varies between 21 V to 32 V (V_{DC} in Figure 3). Communication on the bus is done at 9600 baud asynchronously. A logic one is represented by the DC-level on the bus staying constant. For a logic zero, the bus is pulled 3 V to 10 V below the DC-level first. This is called the active pulse which has a duration of typically 35 µs. Following immediately after is the equalisation pulse. During this time, the voltage can swing up to 13 V above the DC-level and will decay exponentially in 69 µs.

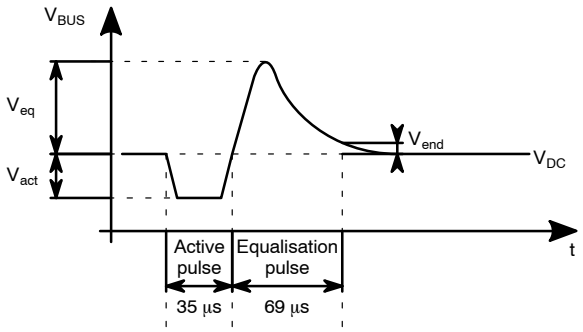

Figure 3. Waveform Seen on the Bus when Transmitting a Logical Zero

Figure 3 shows a typical waveform on the bus representing a logical zero.

Fan-in

Every device connected to the KNX-bus will draw current from the bus to supply the application. The KNX standard specifies the current should be limited to the real need. For every KNX-device the maximum current draw is specified in its datasheet according to the fan-in-model [1]. The fan-in-model is used to determine how many devices can be connected to one physical segment of the bus. All the ON Semiconductor KNX transceivers contain a built-in mechanism to keep the draw within the value specified in its datasheet. This makes sure that the device complies with the standard.

The fan-in pin sets the maximum current drawn from the bus. The transceiver will actively keep the current below the set limit.

Both transceivers (NCN5121 and NCN5130) have two pre-defined fan-in modes. These can be selected by either connecting the fan-in pin to GND or leaving it floating. Leaving it floating, the maximum bus current is limited to 10 mA. Tied to GND the limit is set to 20 mA.

The NCN5130 also offers an external fan-in mode. In this mode the current limit can be set linearly from 5 mA to 40 mA. This is achieved by connecting a resistor with a value of 10 kΩ to 93.1 kΩ to the fan-in pin. The fan-in-model [1] specifies discrete current classes. When designing the application and defining the current consumption, the next higher value of one of the classes must be selected. According to section 3.3 of the KNX test specification [2] the maximum allowed bus current consumption for a fan-in-model of 10 mA is 12 mA. For other fan-in models it is allowed to scale this value accordingly. For example, a 20 mA fan-in-model allows to draw 24 mA from the bus.

Table 1. RECOMMENDED FAN-IN RESISTOR VALUES

R_3	$I_{bus,lim}$ (Typical Values)	Current Class (Note 1)
∞	11.4 mA	10 mA
0 Ω	22.3 mA	20 mA
10 kΩ	43.9 mA	40 mA
13.3 kΩ	33.0 mA	30 mA
20 kΩ	22.1 mA	20 mA
42.2 kΩ	10.7 mA	10 mA
93.1 kΩ	5.1 mA	5 mA

1. According to the fan-in-model [1].

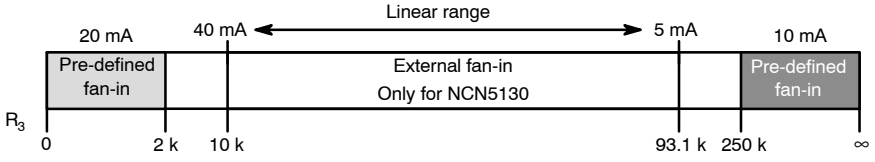

Figure 4. The Different Fan-in Settings

A list of recommended fan-in resistor values can be found in Table 1. For the listed resistor values, the corresponding current limits are specified in the datasheet.

If a resistor value is used, other than the ones specified in Table 1, the following formula can be used to calculate the corresponding bus current limit:

$$I_{bus,lim} = 4 \times 10^{-4} + \frac{434}{R_3}\ A \qquad \text{(eq. 1)}$$

Buffer Capacitor

Besides the maximum allowed current drawn from the bus, the KNX standard also specifies at which rate the bus current is allowed to change. This requirement introduces the need for a large buffer capacitor. When the load current changes abruptly this capacitor must deliver the required energy. The KNX-transceiver will charge the capacitor again after the load step using a fixed current slope.

According to the KNX test specification [2] a device with a fan-in-model of 10 mA is allowed to change its current draw from the bus with a slope of 0.5 mA/ms. Section 3.3 specifies that this can be increased accordingly with the fan-in-model. The following formula can be used to calculate the allowed bus current slope:

$$\frac{\Delta I_{bus}}{\Delta t} = 0.05/ms \cdot I_{fan-in-model} \qquad \text{(eq. 2)}$$

The datasheet (pages 18–19) of the NCN5121/NCN5130 describes how to dimension the buffer capacitor. The KNX Family Efficiency Calculator[3] is a tool developed to help customers with this dimensioning.

Common Mode Choke

If desired optionally a common mode choke such as the Murata 50475C can be mounted on the footprint of L1. This helps to block common mode disturbances, but in most applications, this is not required.

Before soldering the choke on the foreseen footprint of L1, the tracks shorting the component must be cut.

Figure 5. Wago 243–211 Terminal Block

[3] https://www.onsemi.com/pub/Collateral/KNX%20FAMILY%20EFFICIENCY%20CALCULATOR.XLSM

Power

The board is powered through the KNX-connector. These two pins (KNX+/KNX- in Figure 9) mate with a typical KNX terminal block such as the Wago 243–211, illustrated in Figure 5. No additional connection is required as the board will generate its own supply voltages. An input voltage up to 30 V is tolerated. Using a standard KNX power supply is the safest option as it generates the correct voltage and has a built-in protection.

It is possible to use a laboratory supply, but be sure to correctly set the output voltage to avoid damaging the board. By using a laboratory power supply, it is not possible to send messages on the KNX-bus. To enable communication on the bus, a special choke must be placed between power supply and development board. An example of such a choke is the Siemens GAMMA Choke N 120/02.

To power the microcontroller development board there are several options.

- Most modern microcontroller development boards can be supplied through the 3V3-pin, this eliminates the need for additional LDO's, and lowers the overall power consumption.
  On the shield, there is always a 3.3 V supply present, which is also used to supply the KNX transceiver. This supply voltage can be routed to the 3V3-pin on the Arduino headers by shorting J11 (Figure 6).
- Arduino-compatible development boards typically accept a supply voltage of 7 V to 12 V, either through the on-board DC-jack (if present) or the VIN-pin on the headers.
  The shield can supply the microcontroller through the VIN-pin. When J10 is shorted (see Figure 6), the 9 V generated by DC-DC2 is routed to the VIN-pin. In this configuration, the whole system is supplied through the KNX-bus and no additional power supplies are required.
- The microcontroller development board may be supplied through an external supply. This occurs when debugging the board through USB with the KNX-connector disconnected. In this case remove both J10 and J11 (Figure 6).

Debugging

During the development of the application code it is very likely the microcontroller development board is powered through the USB connection with the PC while debugging. This introduces the risk that the KNX-transceiver is powered through the reset line. Current can flow from the NRST-output of the debugger into the RESETB-pin of the transceiver through the internal ESD diodes as shown in Figure 7. As a result, the NRST-line might be pulled low, resetting the microcontroller. This makes it impossible to debug the application.

To avoid this situation a transistor is added in series with the NRST-line as shown in Figure 8. If the 3.3 V from the KNX transceiver is absent, the transistor does not conduct, and prevents current flow into the RESETB-pin. However, if the 3.3 V supply is present, it is still possible for the KNX transceiver to pull the NRST-line low. **It is not necessary to use this circuitry in the end application. In almost all applications, the microcontroller will be powered from the transceiver's supply, and this situation will never occur.**

KNX power supplies are isolated. This means that the KNX-ground is not connected to earth. On most microcontroller development boards the ground connection on the Arduino headers is connected to USB ground. The USB ground on a PC is always connected to the earth potential. So when connecting the development board to the PC the KNX-ground is connected to the earth potential. This might lead to the "pick-up" of interferences leading to communication errors. To avoid these it is a good practice to use an USB-isolator, such as the Olimex USB-ISO.

Powering External Circuitry

The transceiver's 20 V LDO and DC-DC2 converter can be used to power additional circuitry, e.g. a relay. When additional shields are stacked, which take their power from the VIN-pin, these can be powered by connecting DC-DC2 to the VIN-pin. This can easily be done by placing J10 as shown in Figure 6.

If the additional circuitry is not a shield or if the shield is powered in another way, the three pin screw terminal can be used. Figure 9 shows the pin-out of this connector. It is also possible to power additional circuitry using DC-DC1. This converter delivers a fixed 3.3 V with a maximal output current of 100 mA, ideal to supply, for example, a microcontroller.

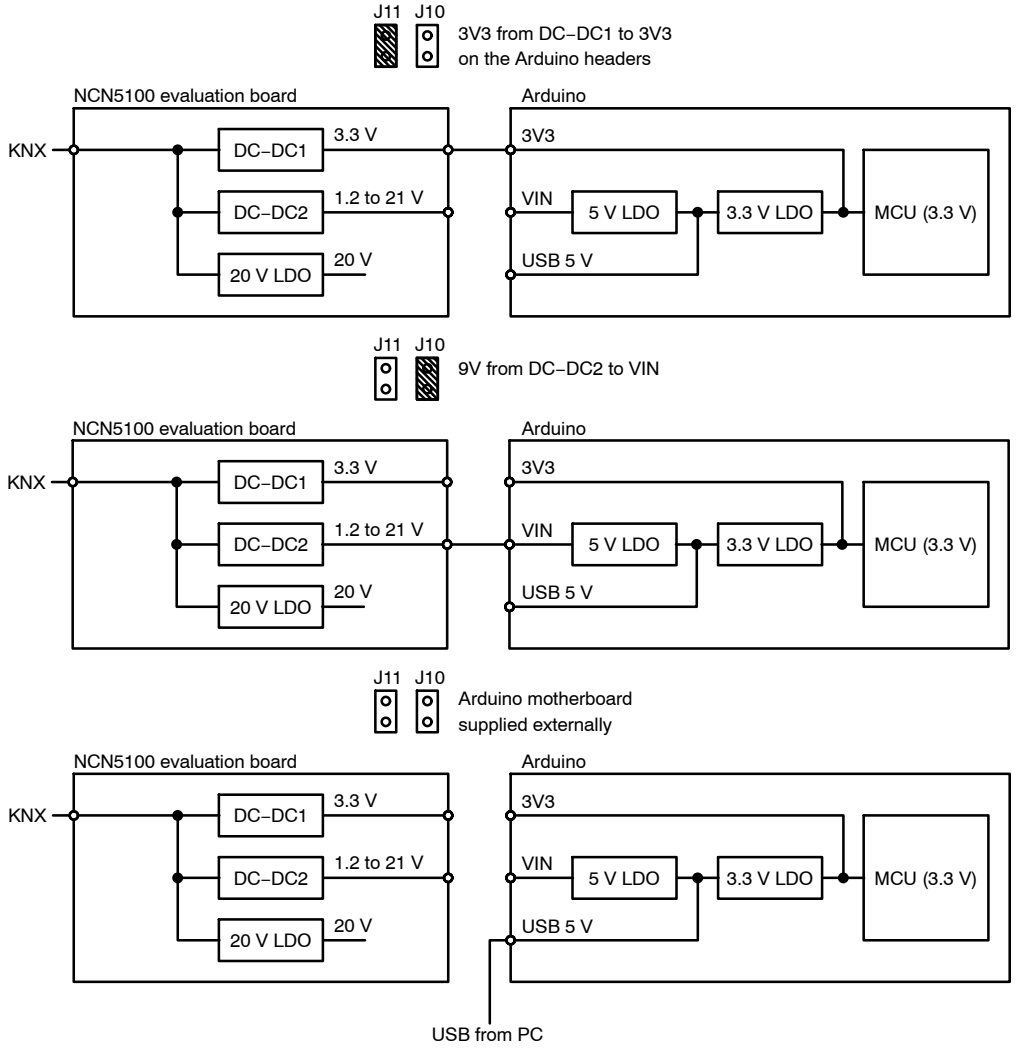

Figure 6. Jumper Settings for the Three Possible Supply Configurations

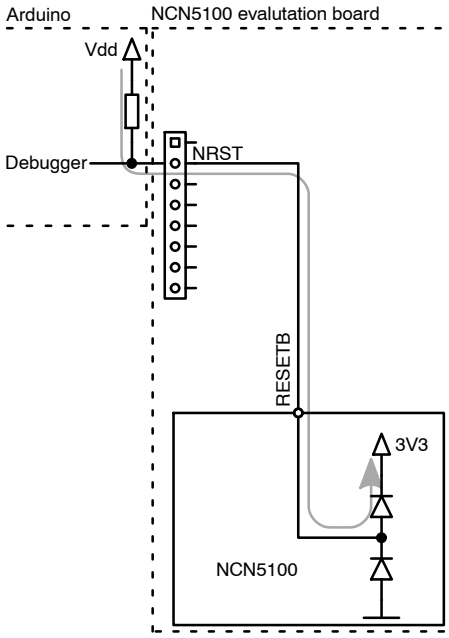

Figure 7. The Internal ESD Diodes Pulling the NRST-line Low

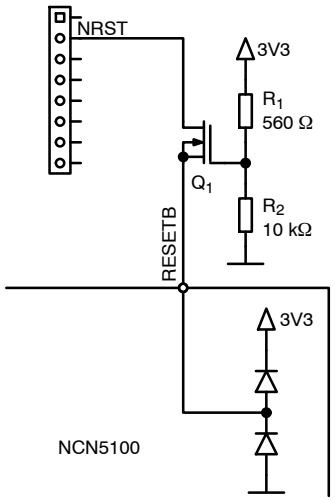

Figure 8. The Transistor Q1, Prevents Current Flow when the 3.3 V is Not Present

Adjusting the DC-DC2 Output Voltage

DC-DC2 is adjustable and can be configured to generate a voltage between 1.2 V to 21 V. This enables supplying a very wide range of applications. By default, the output voltage is set to 9 V. This makes it suitable to supply an Arduino-compatible development board, which typically accepts an input range of 7 V to 12 V.

To adjust the output voltage the values of the feedback resistors must be changed. These are located at the bottom left corner of the PCB, making them easily resolderable. The required resistor values can be calculated from:

$$R_{18} = R_{22} \cdot \frac{V_{VDD2} - 1.2}{1.2} \qquad \text{(eq. 3)}$$

Or use the KNX Family Efficiency Calculator[4] which can be found on the ON Semiconductor website.

Inputs and Outputs

Arduino Header Pin-Out

Most of the buttons and LEDs are connected to digital pins on the Arduino headers. Two of the buttons and one LED are connected to analog input pins. This was done to keep the I^{2}C-pins free for other purposes. The same applies for the TREQ-pin.

The SAVEB-pin is connected to a digital pin which has interrupt capabilities. This is necessary to provide a signal to the microcontroller as fast as possible indicating the bus voltage is dropping.

All the LEDs are connected to PWM-capable pins, allowing the application to dim the LEDs if desired. A complete net list for the microcontroller connections is given in Appendix A, Table 4 and in Appendix B, Table 5.

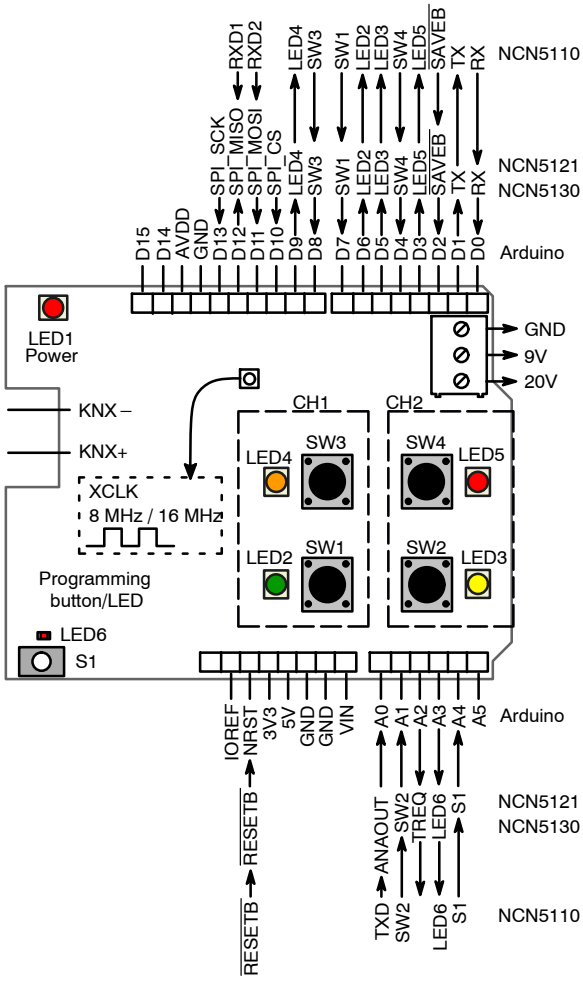

Figure 9. Evaluation Board Connectivity (KNX-Shield)

[4] https://www.onsemi.com/pub/Collateral/KNX%20FAMILY%20EFFICIENCY%20CALCULATOR.XLSM

User Buttons and LEDs

The shield has 4 on-board push buttons (SW1...4) and 4 LEDs (LED2...5) to enable the development of switching apps in particular. For a dimmer application the four buttons are split into two groups marked on the PCB as channel1 and channel2 (CH1/CH2). The upper button in the channel is used to dim up, whilst the other one is used for dimming down. Refer to Appendix A, Table 4 and Appendix B, Table 5 to see how these are connected to the I/O pins of the microcontroller.

It is possible to stack other shields containing I/Os which are used for the end application. Remove R26−R29 and R33−R36 if the buttons or LEDs conflict with the pin-out of the other shields used.

Programming Push Button and LED

To assign an individual address to a device in a KNX-network, the device must be put into programming mode. The simplest way to do this is by pressing the programming button (S1). LED6 indicates if the device is in programming mode.

It is possible to customize the entering in programming mode e.g. pushing two buttons simultaneously.

Microcontroller Clocking

NCN5130 and NCN5121 have the capability to deliver a clock signal to the microcontroller. This clock signal is available on the XCLK-pin of the transceiver and routed to a 2.54 mm header pin on the shield (See Figure 9). Because the Arduino headers do not foresee a dedicated pin to pass clock signals, it is mandatory to route this signal manually to the microcontroller. This is only necessary if it is desired to use this signal to clock the microcontroller. In most cases the microcontroller will be clocked from its internal RC-oscillator or from an external crystal.

By default, the clock signal on the XCLK-pin is 16 MHz. It can be changed to 8 MHz by tying the XSEL-pin to ground: De-solder R23 and solder a 0 Ω resistor on the pads of R30.

Digital Communication Interface

Both the NCN5121 and NCN5130 implement the mac layer of the OSI model as shown in Figure 10. They will handle the coding and decoding of messages, sending acknowledges, etc... Critical low level timings such as the duration of the active pulse are all managed by the transceiver. The transceiver makes sure that the collision avoidance[5] is handled correctly without any intervention by the host controller. This greatly reduces the software development effort. To communicate with the mac layer both a UART- and SPI-interface are supported. Note that when the transceiver operates in SPI-mode it acts as the master. The microcontroller must support slave mode in order to be able to communicate with the transceiver. To select in which mode the KNX-transceiver operates (UART or SPI) the MODE2-pin is used. When tied to GND using R32, the transceiver operates in UART-mode. Tying it to V_{DD1} using R25 puts the transceiver in SPI-mode.

[5] CSMA/CA: Carrier-sense multiple access with collision avoidance.

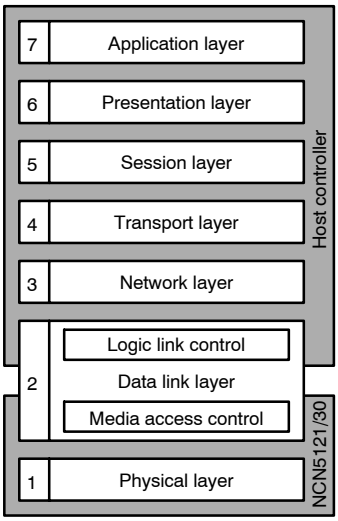

Figure 10. Placement of the Transceivers in the OSI Model

560 Ω resistors protect the I/O lines going to the microcontroller. Depending on which resistors are mounted either the UART or the SPI-lines are connected. If desired it is possible to transform a UART shield into SPI and vice versa by soldering/de-soldering the resistors as listed in Table 2.

Table 2. COMMUNICATION INTERFACE RESISTOR MOUNTING OPTIONS

Communication Interface	Resistor Mounted
UART	R16, R17, R32
SPI	R9, R11, R12, R13, R15, R25

Table 3. SELECT THE RIGHT BAUD RATE USING J1/J2

J2	J1	Parity Bit	Baud Rate
0	0	even	19 200 bps
0	1	even	38 400 bps
1	0	none	19 200 bps
1	1	none	38 400 bps

Selecting The Baud Rate

Jumpers J1 and J2 allow easy configuration of the baud rate and parity. This is only used in UART-mode. In SPI-mode, the communication speed is fixed to 500 kbps.

To make the UART-communication more robust, it is possible to enable the transmission of an even parity bit with every data byte. For the complete settings refer to the silkscreen on the shield or to Table 3.

Analog Communication Interface

The NCN5110 transceiver doesn't contain any digital functionality, implementing only the physical layer of the OSI model. Both the TXD- and RXD-lines are directly connected to the KNX-transmitter/receiver.

Pulling the TXD high will make the transceiver drop the bus voltage as shown in Figure 11. Once the transmit line is pulled low again, the transceiver will put an equalisation pulse on the bus. The duration the bus voltage stays by an amount of V_{act} below V_{DC}, is determined by the microcontroller. As a consequence the microcontroller is also responsible for collision detection and avoidance. As well as the encoding and decoding of messages, sending acknowledges, etc... must be implemented in the microcontroller, increasing the software complexity.

The RXD-line will become high when an active pulse is detected on the bus. As the transceiver also receives the data itself transmitted on the bus, this line will also become high during transmission.

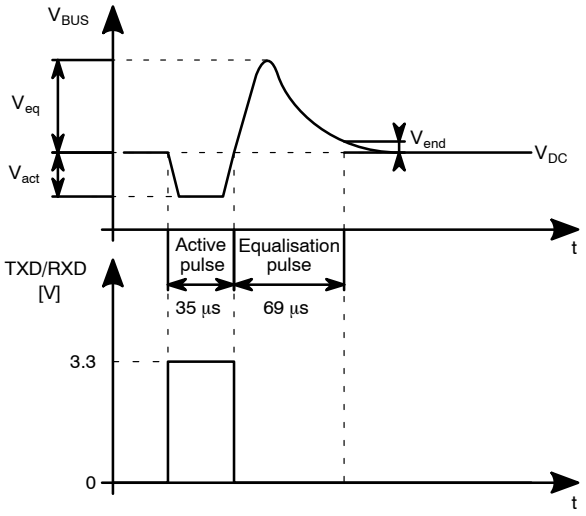

Figure 11. Communication with the NCN5110 and the Corresponding Levels on the KNX-Bus

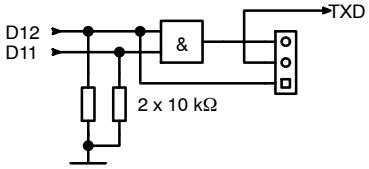

Figure 12. An AND Port Can be Used to Combine the Signals Coming from Two GPIO Pins

Enable Interface

The timing of the pulses which drive the NCN5110 are extremely time critical. Some microcontroller families have special timer modes which can be used to generate the correct pulses. Using these modes, would limit the use of the software to a certain microcontroller family.

An AND port combines the signals coming from D11 and D12. The schematic is shown in Figure 12. It provides a mechanism to set and clear the transmit signal, without the use of special timers only available in specific microcontroller families.

Two timers can be used, one to generate a rising edge, the other to generate a falling edge. Both signals are combined to create the desired transmit signal as shown in Figure 13.

Both input pins of the AND port are pulled low. This ensures that during the startup of the microcontroller, the transceiver won't transmit.

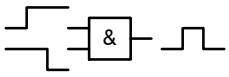

Figure 13. Combination of a Rising and Falling Edge to Create the Transmit Signal

PCB LAYOUT GUIDELINES

When designing a PCB for the KNX-transceiver it is important to take certain layout aspects into consideration. The following good practices will help to improve the EMC performance of the whole application. The Arduino shield is a two-layer PCB, with the main ground plane on the bottom layer. Empty space on the top layer is filled in with ground copper, but this is not a ground plane.

DC-DC Converters

Electromagnetic interference is dominated by the DC-DC converters. These converters switch at frequencies around 300 kHz. Without due consideration for PCB layout, radiated emissions can become a serious issue.

Figure 16 shows an example schematic of an inverter driving a capacitive load. The PCB tracks going to and coming from the load will act as an inductor at high switching frequencies. The return path can be the common circuit ground, but this is not always the case!

When constructing the PCB layout it is very important to pay attention to the signal return path.

The first situation in Figure 14 shows a single-layer design. Here the signal and return path form a large loop, which will act as an antenna at higher frequencies.

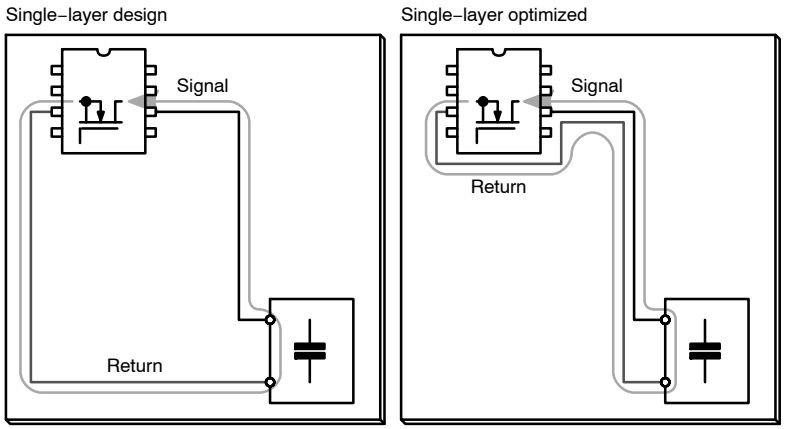

Figure 14. Optimizing the Return Path in a Single-layer Design

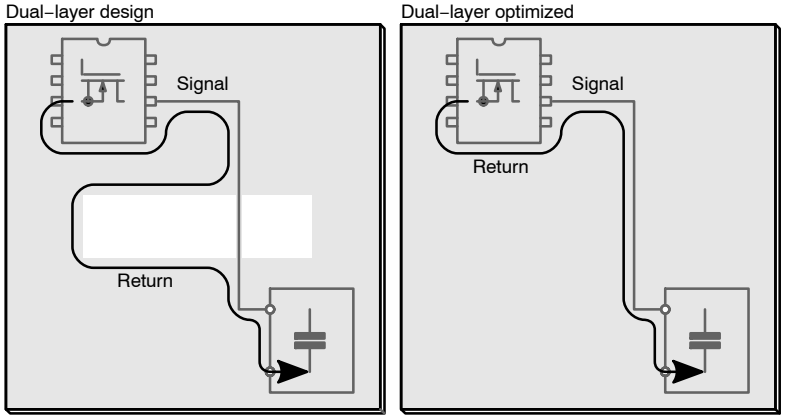

Figure 15. Optimizing the Return Path in a Dual-layer Design

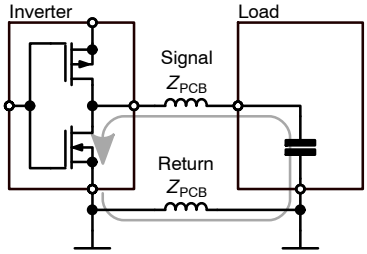

Figure 16. Inverter Principle Schematic Showing a Critical Current Loop

This layout can be improved significantly by routing the signal and return path close to each other. They should be routed as if they were a differential pair.

In most circuit designs, the return path for most signals is the common circuit ground. For these circuits using a two- or four-layer PCB with the main ground on the bottom- or inner-layer is the recommended choice. It simplifies the layout work and makes it much easier to create optimal return paths.

Still care has to be taken during the design, as it is easy to overlook common mistakes. Figure 15 shows a situation where there is a slot in the ground plane. The return path now goes around the slot creating a slot antenna.

Ideally the bottom ground plane should never be interrupted.

Figure 17 shows the current loops for the two DC-DC converters on the Arduino shield. All the components on the shield are placed and routed to minimize the loop surface areas.

When the DC-DC converter switches on its top transistor, the instantaneous current spike is drawn from the small 100 nF capacitor C8. As these current spikes are short, they will have a high frequency. So the most critical loop, is the current flowing from C8 into the parasitic capacitance at V_{SW} as shown in red. To keep this loop very small, C8 must be placed as close as possible to the VIN-pin. If possible, place it right next to it as in Figure 18.

Keeping all the tracks on the top layer avoids any disruptions in the bottom ground layer and resistance/inductance being added by vias. The two grey arrows show the larger current loops created by the DC-DC converter. These should also be kept as short as possible to minimize radiated emissions. Figure 18 shows the optimal layout, used on the shield, to keep these loops small.

The larger buffer capacitor C9 can be placed further away from the VIN-pin, as long as the small ceramic capacitor C8 is placed very close to it.

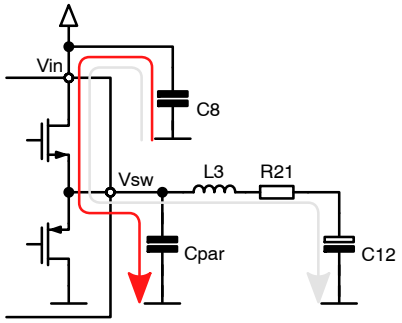

Figure 17. Schematic Showing the DC-DC Converter Current Loops

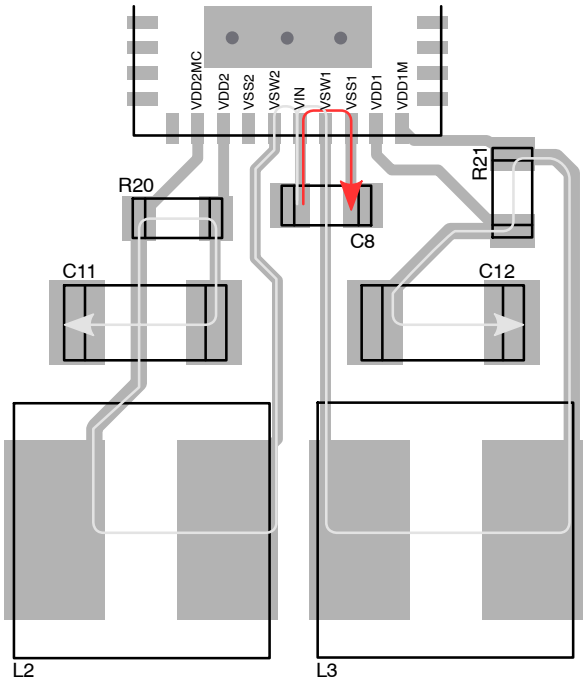

Figure 18. DC-DC Converter Current Loops on the Arduino Shield

TVS Diode

It is important to optimize the layout of the Transient Voltage Suppression (TVS) diode in order to effectively protect the transceiver against surges. When a surge occurs, the TVS diode must clamp the voltage to a level which doesn't damage the transceiver. To achieve this, the series resistance should be as low as possible.

This can be done by connecting KNX-directly to the TVS diode before being routed to the rest of the PCB ground as shown in Figure 20. This ensures that the current path to the TVS has the lowest resistance and no transient current will flow to the transceiver.

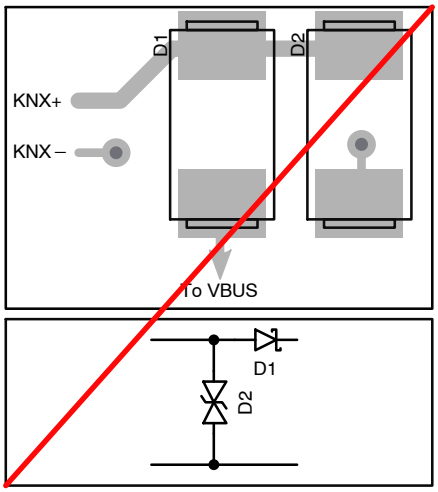

Figure 19. Wrong Layout for the TVS Diode

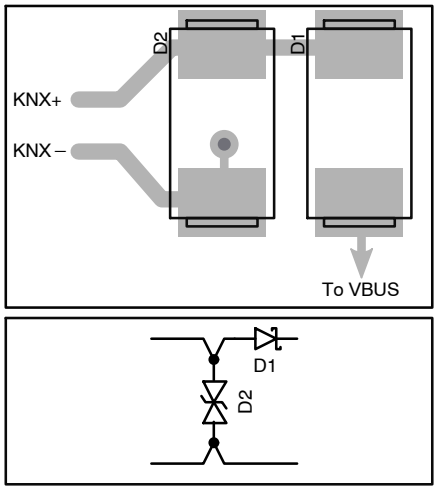

Figure 20. Optimal Layout for the TVS Diode

GETTING STARTED

The Arduino shield comes with demo software developed by Tapko Technologies GmbH. The software includes a demo version of KAIstack which runs on a STM32F103-NUCLEO board. This software contains all the necessary software components to connect to the KNX-bus and comes with a variety of demo applications. The demo version of KAIstack can be used to start developing custom application software.

The following limitations apply to the demo version:

- Limited to 16 group addresses, 16 associations and 16 communication objects instead of 255.
- Application interface objects have been removed.
- The rout-count is set to zero in the network layer, limiting the application use to only one line.
- There are no repetitions on the transport layer.
- It is not possible to change the individual address of the device through ETS.
- Only one derivative is supported.

Prerequisites

Listed below are all the components needed to construct a small KNX-network with the NCN5100ASGEVB.

- KNX power supply (including a choke).
- USB-KNX interface to communicate with ETS on the PC.
- A demo version of ETS.
- STM32F103-NUCLEO board to plug the shield into.
- Any version of the NCN5100ASGEVB.

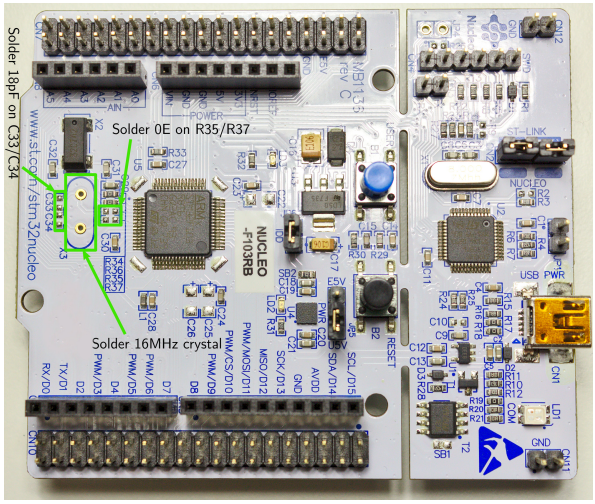

Figure 21. Hardware Modifications on the Top Side of the Nucleo Board

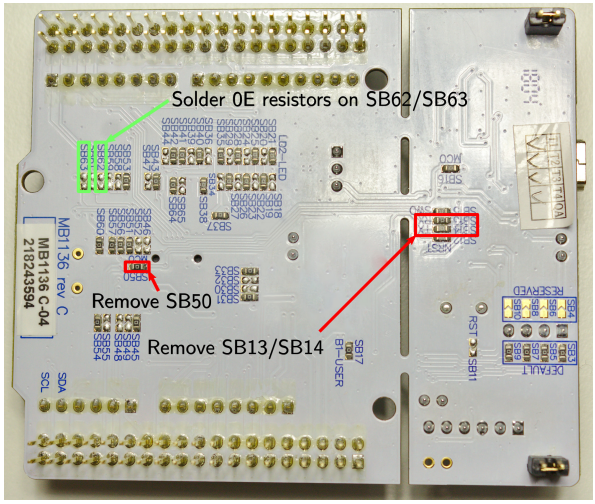

Figure 22. Hardware Modifications on the Bottom Side of the Nucleo Board

Hardware Modifications

To get started with the demo software, a NCN5110, NCN5121 or NCN5130 Arduino shield is required in combination with a STM32F103-NUCLEO board. In order to get the software running on the microcontroller, a couple of hardware modifications are required.

To meet the timing requirements to communicate on the KNX-bus, it is mandatory to have a more accurate clock than the on provided by the internal RC-oscillator of the microcontroller. Two options are suggested below.

Placing a Crystal

Mount a **crystal** in the X3 footprint on the Nucleo board. This crystal must have a frequency of 16 MHz. For the recommended value of the loading capacitors C33/C34, refer to the datasheet of the crystal. A good crystal is the 9B-16.000MEEJ-B, which needs loading capacitors of 18 pF.

To get the crystal working on the Nucleo board the following configuration is required (Figures 21 and 22):

- Place 0 Ω resistors at R35 and R37.
- Solder the loading capacitors on C33 and C34.
- Remove the 0 Ω resistor at SB50.
- Solder the crystal on X3.

Apply An External Clock

The second option is to use an external clock.

Use the **XCLK-output** of the KNX-transceiver as a clock input for the microcontroller. By tying the XCLKC-pin high/low a clock frequency of 16 MHz or 8 MHz can be selected. By default on the Arduino shield, the XCLKC-pin is pulled high, meaning a clock signal of 16 MHz is present on the XCLK-pin. This method has the advantage that the complete application only needs one crystal.

To use the XCLK-output as a clock signal, the following configuration is required:

- Place a 0 Ω resistor at SB55.
- Remove the 0 Ω resistor from SB50.
- Connect the XCLK-pin on the Arduino shield to pin 29 of CN7 on the Nucleo board. Do this using a wire which is as short as possible.

UART Communication

On the Nucleo board the USART2 interface is by default used to communicate with the on-board ST-LINK. This means that it is not possible to use D0 and D1 on the Arduino headers for UART communication, as they are not connected.

To enable UART communication on the Arduino headers execute the following steps (Figures 21 and 22):

- Remove the 0 Ω resistors from SB13 and SB14.
- Mount 0 Ω resistors at SB62 and SB63.

These steps will disable the communication between the microcontroller and the ST-LINK. Then it is no longer possible to use the Virtual COM-port on the Nucleo board. To keep using the Virtual COM-port, connect another USART peripheral to the ST-LINK. USART3 is a possible candidate which can be used by connecting two wires as follows:

- Connected pin 1 of CN7 (PC10-USART3_TX) to the RX pin on CN3.

- Connected pin 2 of CN7 (PC11-USART3_RX) to the TX pin on CN3.

Setting Up A Network

Once the STM32F103-NUCLEO board is ready, a small network can be set up to get started with the NCN5100ASGEVB.

Connecting Power

There are several options to power the Nucleo board. Refer to Section *Power* for all the possible configurations. To get started, remove the jumpers J10 and J11 from the Arduino shield and place JP5 on the Nucleo in the U5V position. This way the microcontroller will be powered from the USB port while the KNX-transceiver is powered from the KNX-bus.

To power the complete solution from the KNX-bus, place J10 on the Arduino shield and JP5 in the E5V position on the Nucleo.

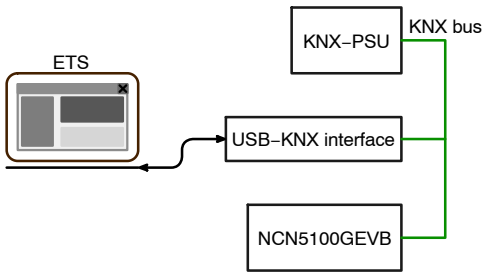

Figure 23. Minimal Network Setup

UART Communication

The demo software from Tapko communicates with the transceiver at 19.2 kb/s using an even parity bit. Place J1 and J2 in the ‘0’-position to select the correct communication speed.

Building The Network

A minimal network setup consists of a KNX power supply, KNX USB-interface and the NCN5100ASGEVB. This setup is displayed in Figure 23. The KNX USB-interface is used to configure the NCN5100ASGEVB through ETS and to send and receive messages.

After setting up the network, connect the USB coming from the KNX USB-interface and the Nucleo to the PC. The physical hardware setup is now complete.

Installing The Software

The microcontroller demo software can be found on the ON Semiconductor website [5]. Download the software, unpack it and execute the installer.

The installer will first ask in which folders to install the software. The first folder will contain KAIstack, the compiler, software examples and the documentation. In the second installation folder, some additional tools and the documentation for KAIstack are installed.

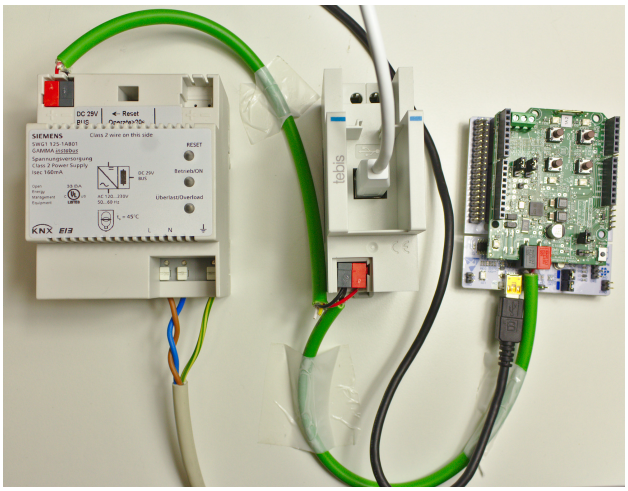

Figure 24. Picture of the Practical Setup

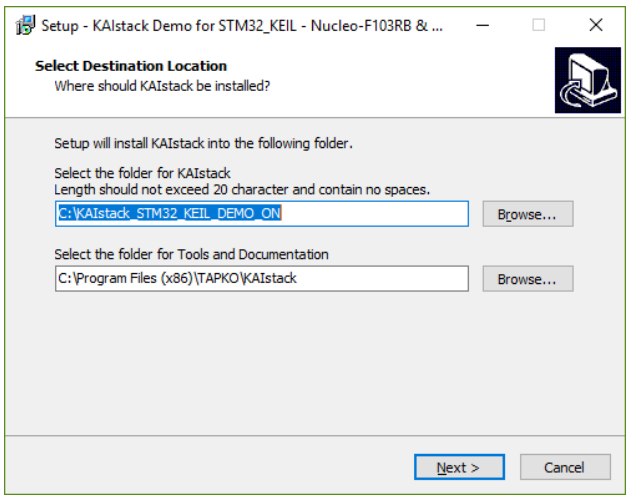

Figure 25. Selection of the Installation Folders

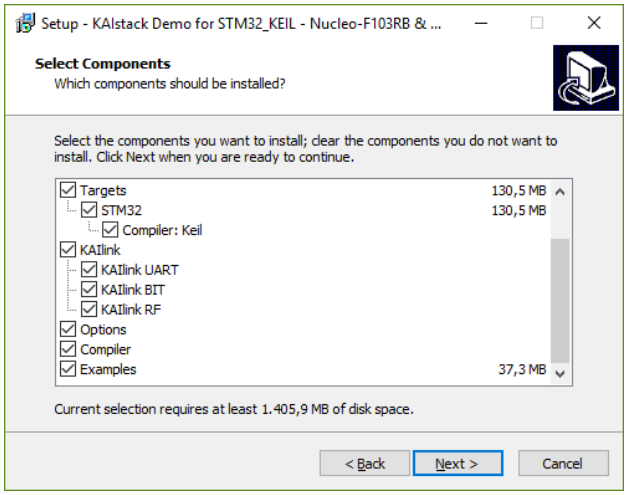

Figure 26. Select which Components to Install

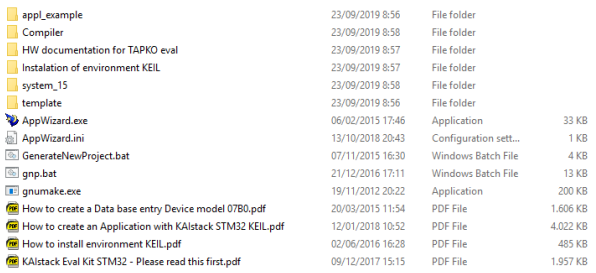

Figure 27. Folder Structure of the KAIstack Installation

Next, the installer gives the option to select which components to install. It is recommended to leave everything selected. When clicking on Next, a summary is given of what will be installed.

Install the software and open the installation folder where KAIstack is installed. The folder structure will look like the one shown in Figure 27.

In the *appl_example* folder, many examples of application programs can be found. Refer to the documentation included with the installation on how to modify the software examples to your needs.

Building and Loading The Software

The folder structure of the first application example *1in1out 07B0* is shown in Figure 28.

Two folders named *dummy* and *tmp* contain some temporary files necessary to compile the program. These files can be ignored.

The *ETS_DB* folder contains an ETS-project, that will be used later on to configure the NCN5100ASGEVB. The folder named *1_IN_OUT_07B0* contains all the files necessary to get started in the KNX manufacturer tool. They can be used to create a catalog entry, product database, etc...

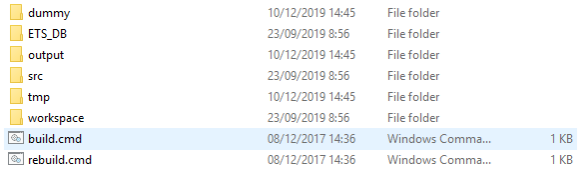

Figure 28. Folder Structure of an Application Example

The final output files generated by the compiler are placed in the *output* folder. The binary that must be loaded in the microcontroller can be found there.

The application program specific source and header files are located in the *src* folder. A file named *project.h* contains all the project specific settings.

These projects are all compiled using the ARM KEIL compiler. It is possible to open the example projects in the KEIL µVision IDE. The necessary files are located in the *workspace* folder. For more information refer to the documentation included with the installation.

Lastly there are two batch files included in the folder. These can be used to build and rebuild the application.

To get started with the previously built setup, one of the example projects must be loaded in the microcontroller. Compile the *1in1out_07B0* example by executing the *rebuild.cmd* batch file. A command window will pop-up showing the progress of the compilation process. It will display a message, as shown in Figure 29 once the compilation is finished. Now the output folder contains a .hex file, which can be loaded in the microcontroller.

To program the microcontroller, the STM32CubeProgrammer tool is used. Open the program after downloading and installing the latest version. In the tool click on *Open File* and select the generated .hex file. Once it is loaded in the tool, click on the Download button to load it in the microcontroller. A window saying File *download complete* should pop up, as shown in Figure 30. Now the KNX-device is ready and the network can be configured.

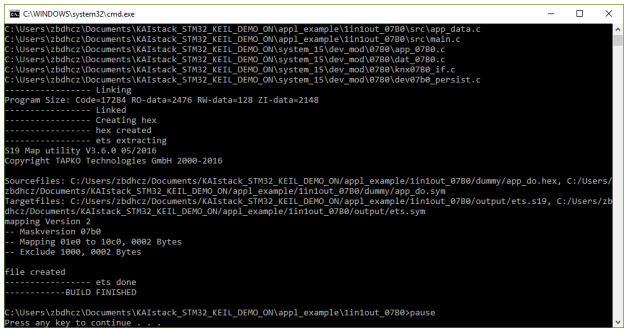

Figure 29. Output Window of the Compilation Process

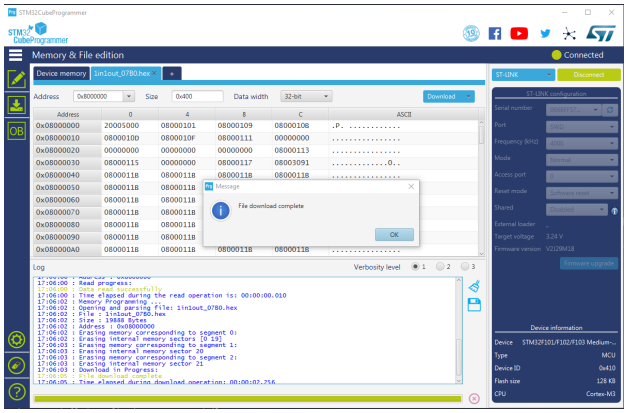

Figure 30. Program the Nucleo Using the STM32CubeProgrammer

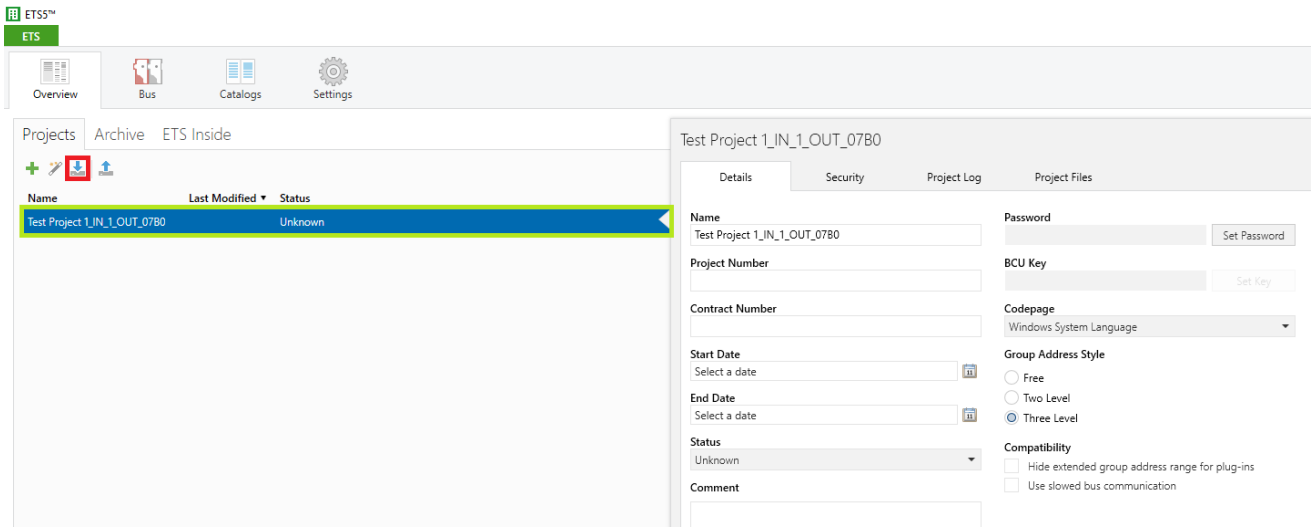

Figure 31. Import the ETS-project Included with the Demo Application

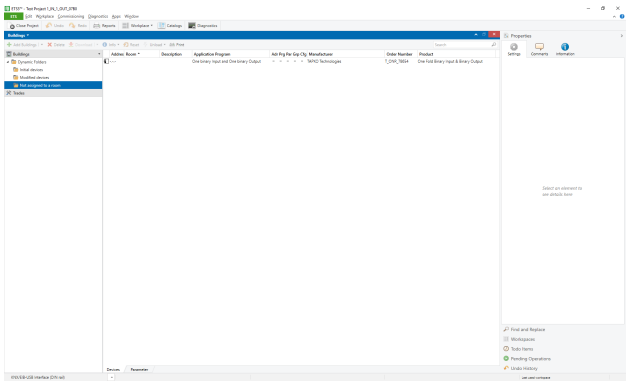

Figure 32. The 1-in 1-out ETS-project

ETS Configuration

Configuring a KNX-network is done through ETS. ETS is a PC tool used by certified KNX-installers to set up a network. To get started, only the basics are explained here. For more information, refer to the official KNX-documentation [4].

The ETS project that is included with the demo application has to be imported. Click on the import button shown in Figure 31. Now select the *Test Project 1_IN_1_OUT_07B0.knxproj* File in the ETS DB folder. When the import is finished the project will appear in the *Projects* pane. Double click on the project to open it.

Because ETS is an installer tool, it is possible to create complete building structures. This makes it easy to keep a good overview of the whole installation and to make modifications in the future. This building structure is created in the Buildings pane on the left.

The NCN5100ASGEVB device can be found under *Dynamic Folders* → *Not assigned to a room*. To be able to use and configure it, it has to be assigned to a room first. A room can not exist on it's own and must be created inside a building. To create a building, click on the word *Buildings* and then *Add Buildings*. Once the building is created, right click on it and select *Add* → *Rooms* to create a room.

To assign NCN5100ASGEVB to the room just created, click on the *Not assigned to a room* folder and drag the device into the room. After the device is linked to a room, an individual address must be assigned to it.

The individual address has a fixed format, and is chosen in such a way that it reflects it's position in the network. It is only used for programming the device. For more information on this topic, refer to the official KNX-documentation [4].

The Tapko demo stack doesn't support changing the individual address. So the device must be given the fixed individual address *1.5.8* as shown in Figure 33. Click on the device in the *Buildings* panel so that the *Properties* panel opens on the right. Under the settings tab the individual address can be found.

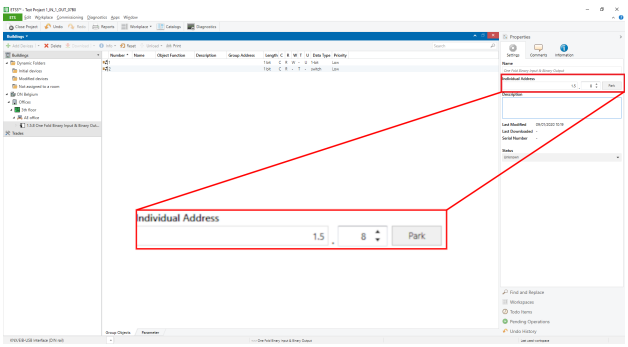

Figure 33. Assigning an Individual Address to the NCN5100ASGEVB

Now the group addresses have to be assigned in order for the device to communicate on the bus. Refer to the official KNX-documentation [4] for more information on how the communication system with group addresses works. Click on the device in the *Buildings* panel and go to it's *Group Objects* tab, as shown in Figure 34. It will show all the supported group objects and the group addresses which are assigned to it. The assigned group addresses will be blank. To assign a group address to a group object, right click on it and select *Link with....* A window as shown in Figure 35 will pop up. In this window, select *New*. In this tab a new group address can be created which will be immediately assigned to the group object. Assign group address *0/0/2* to the bit group object and *0/0/1* to the switch group object. Give them both an appropriate name. The switch group object is used to send a bit value on the bus every time the button SW3 is pressed. The bit group object is used to control LED3 on the shield.

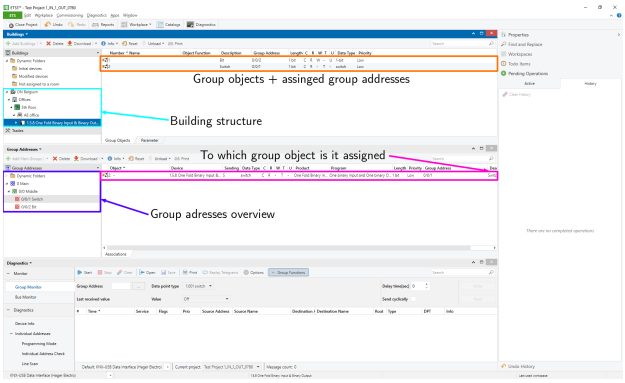

Figure 34. The ETS-project after Completing the Set Up

It is possible to review and adjust the group addresses/names in the *Group Addresses* panel (*Workplace* → *Open New Panel*).

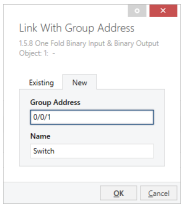

Figure 35. Assign a New Group Address

Now the complete project has been configured and should look like Figure 34. This configuration can now be loaded in the NCN5100ASGEVB. Make sure that the USB-KNX interface is connected to the PC. Right click on the device in ETS and select *Download* → *Full download*.

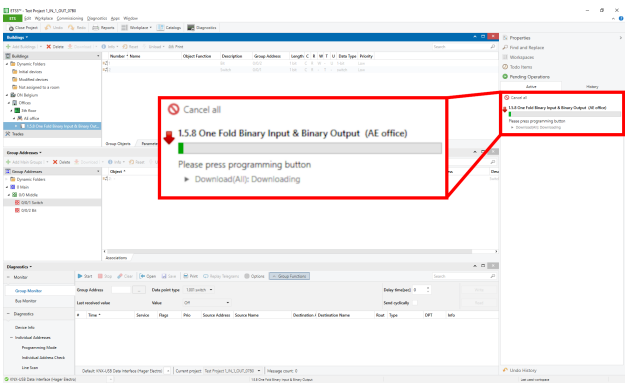

Figure 36. Downloading the Full Configuration in the NCN5100ASGEVB

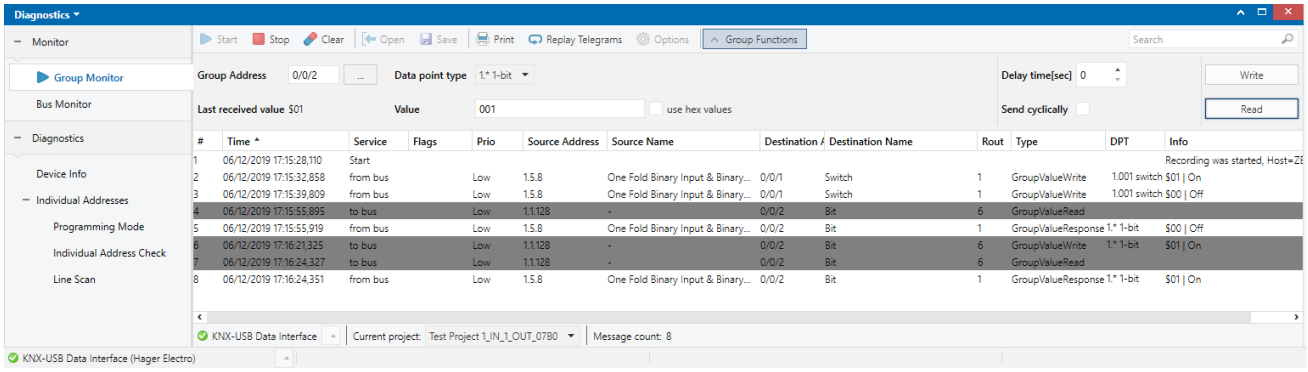

Figure 37. The Group Monitor Showing the Group Communication on the Bus

ETS will now ask to press the programming button on the NCN5100ASGEVB. It can be found on the lower left corner of the shield. After pressing the button, the LED above will light up. Now ETS will start the download process.

Once the download has finished, open the *Diagnostics* panel by clicking on the *Diagnostics* button on the top menu bar. In this panel it is possible to monitor what happens on the network and control the network through the USB-KNX interface. Press the *Start* button to start monitoring the network.

Now every time button SW3 on the shield gets pressed a message is sent on the bus by the NCN5100ASGEVB. The *Diagnostics* panel shows who is sending the message, what group address is being sent and what value. The value should toggle between On and Off every time the button is pressed.

It is possible to send messages on the bus through the *Diagnostics* panel to control one of the LEDs on the shield. In the *Group Address* field enter *0/0/2*.

When pressing the *Read* button, the USB-KNX interface sends a read request on the bus for group object *0/0/2*. The NCN5100ASGEVB will respond with the current state of LED3, which is Off.

In the *Value* field enter 1. When the *Write* button is pressed, the USB-KNX interface sends group object *0/0/2* on the bus with the value On. LED3 on the shield should now light up. When pressing the *Read* button again the device will now respond with On.

BIBLIOGRAPHY

Standards

[1] *The KNX Standard v2.1 – KNX Hardware Requirements and Tests – Part 4–1: Safety and Environmental Requirements – General.* KNX, 2013.

[2] *The KNX Standard v2.1 – System Conformance Testing – Part 8–2–2: Medium Dependant Layers Tests – TP1 Physical and Link Layer Tests.* KNX, 2013.

Internet

[3] *KNX Association*. 2020, accessed January 28, 2020. url: https://www.knx.org.

[4] *KNX Training Centres*. 2020, accessed January 28, 2020. url: https://www.knx.org/knx–en/for–professionals/community/training–centres/index.php.

[5] *Wired connectivity solutions.* 2020, accessed January 28, 2020. url: https://www.onsemi.com/PowerSolutions/segment.do?method=subSolution&segmentId=IoT&solutionId=19116&subSolutionId=19126.

APPENDIX A – MICROCONTROLLER NET LIST NCN5100AS-1

Table 4. MICROCONTROLLER PINS LIST

Pin Arduino Headers	Connected to	Function	MCU Pin Direction
D0/RX	SDO/TXD	UART receive line	IN
D1/TX	SDI/RXD	UART transmit line	OUT
D2	SAVEB	Save data indication	IN
D3/PWM	LED5	CH2 Red up button LED	OUT
D4	SW4	Up button CH2	IN
D5/PWM	LED3	CH2 Yellow down button LED	OUT
D6/PWM	LED2	CH1 Green down button LED	OUT
D7	SW1	Down button CH1	IN
D8	SW3	Up button CH1	IN
D9/PWM	LED4	CH1 Orange up button LED	OUT
D10/CS	CSB/UC1	SPI chip select	IN
D11/MOSI	SDO/TXD	SPI MOSI	IN
D12/MISO	SDI/RXD	SPI MISO	OUT
D13/SCK	SCK/UC2	SPI clock	IN
A0	ANAOUT	Analog multiplexer output	IN (analog)
A1	SW2	Down button CH2	IN
A2	TREQ	Transmission request	OUT
A3	LED6	Programming LED	OUT
A4	S1	Programming button	IN

APPENDIX B – MICROCONTROLLER NET LIST NCN5100AS-2

Table 5. MICROCONTROLLER PINS LIST

Pin Arduino Headers	Connected to	Function	MCU Pin Direction
D3/PWM	LED5	CH2 Red up button LED	OUT
D4	SW4	Up button CH2	IN
D5/PWM	LED3	CH2 Yellow down button LED	OUT
D6/PWM	LED2	CH1 Green down button LED	OUT
D7	SW1	Down button CH1	IN
D8	SW3	Up button CH1	IN
D9/PWM	LED4	CH1 Orange up button LED	OUT
D11	RXD2	Data input NCN5110	OUT
D12	RXD1	Data input NCN5110	OUT
A0	TXD	Data output NCN5110	IN
A1	SW2	Down button CH2	IN
A3	LED6	Programming LED	OUT
A4	S1	Programming button	IN

APPENDIX C – LIST OF TESTED PLATFORMS

Table 6. TESTED PLATFORMS

Manufacturer	Development Board	Microcontroller
STMicroelectronics	NUCLEO−F103RB	STM32F103RB
Cypress	CY8CKIT−044	CY8C4247AZI−M485
Waveshare	XNUCLEO−F103RB	STM32F103RB

APPENDIX D – NCN5130ASGEVB

UART-version

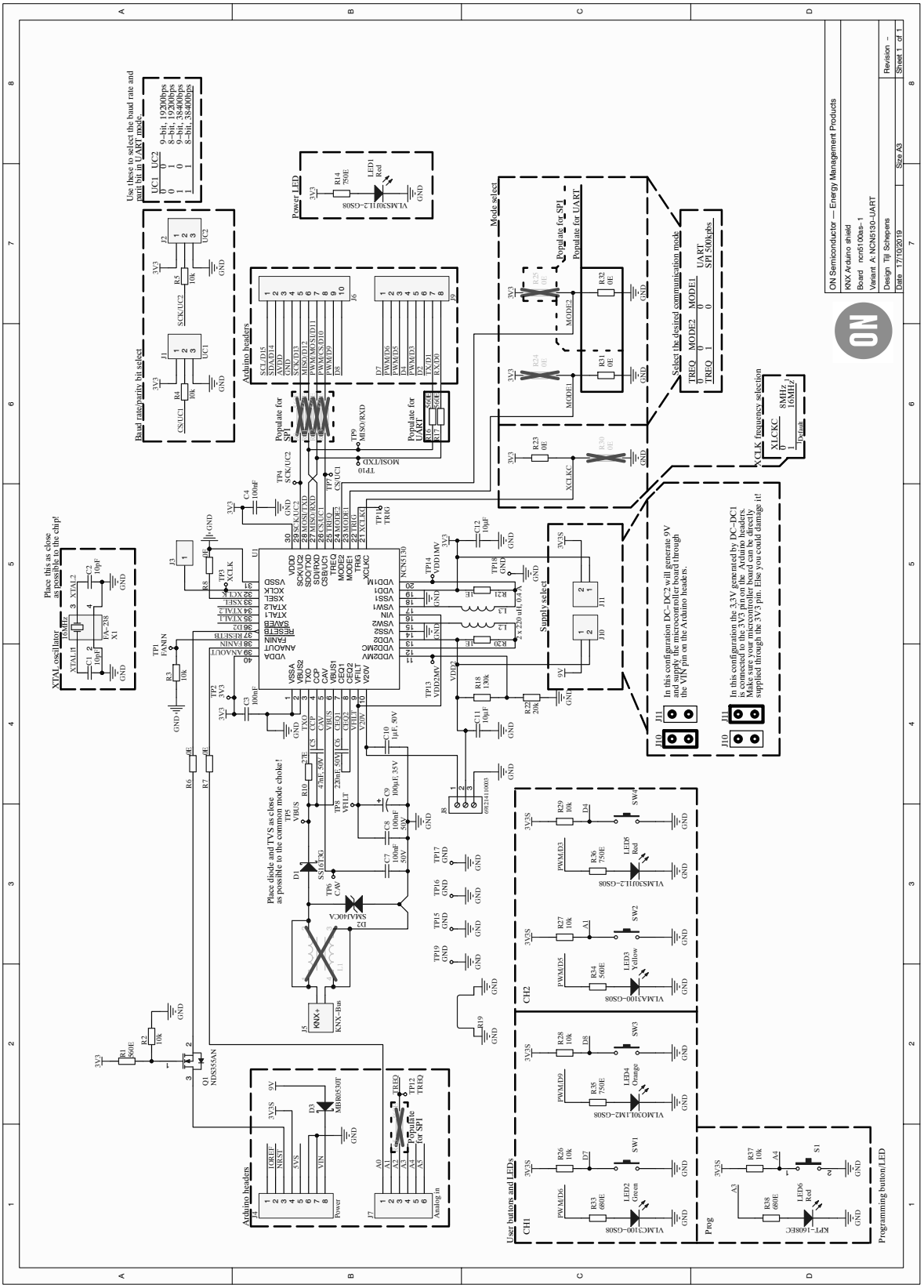

Figure 38. Schematic

Table 7. BILL OF MATERIALS UART-VERSION

Designator	Qty	Description	Value	Part Number
J1	1	WR−PHD 2.54 mm THT Pin Header, 3p		61300311121
J2	1	WR−PHD 2.54 mm THT Pin Header, 3p		61300311121
J3	1	WR−PHD 2.54 mm THT Pin Header, 1p		61300111121
J4	1	Board-To-Board Connector, 2.54 mm, 8 Contacts, Receptacle, Through Hole, 1 Rows		SSQ−110−03−G−S
J6	1	Board-To-Board Connector, 2.54 mm, 10 Contacts, Receptacle, Through Hole, 1 Rows		SSQ−110−03−G−S
J7	1	Board-To-Board Connector, 2.54 mm, 6 Contacts, Receptacle, Through Hole, 1 Rows		SSQ−106−03−G−S
J8	1	Serie 2141 − 3.50 mm Horizontal Entry Modular with Rising Cage Clamp WR−TBL, 3 pin		691214110003
J9	1	Board-To-Board Connector, 2.54 mm, 8 Contacts, Receptacle, Through Hole, 1 Rows		SSQ−108−03−G−S
L2	1	SMT Power Inductor WE−LQFS, size 4828, 220 μH, 0.4 A		74406043221
L3	1	SMT Power Inductor WE−LQFS, size 4828, 220 μH, 0.4 A		74406043221
Q1	1	N-Channel Logic Level Enhancement Mode Field Effect Transistor, 30 V, 1.7 A, −55°C to 150°C, 3-Pin SOT−3, RoHS, Tape and Reel		NDS355AN
J10, J11	2	WR−PHD 2.54 mm THT Pin Header, 2p		
R6, R7, R8, R23, R31, R32	6	Resistor	0 Ω	RC0603JR−070RL
C10	1	Capacitor	1 μF, 50 V	GCM21BR71H105KA03L
D1	1	Schottky Rectifier, Singel 60 V, 1 A, DO−214AC, 2 Pins, 720 mV	1 A / 720 mV / 60 V	SS16T3G
R20, R21	2	Resistor	1 Ω	RC0603FR−071RL
LED3	1	LED, Yellow, SMD, 2 mA, 2.2 V, 594 nm	2 mA, 2.2 V, 594 nm	VLMA3100−GS08
R19	1	2 (1 x 2) Position Shunt Connector Non-Insulated 0.400 in (10.16 mm) Gold	2 pins	D3082−05
LED4	1	LED, Orange, SMD, 2.4 mm, 2 mA, 1.8 V, 609 nm	2.4 mm, 2 mA, 1.8 V, 609 nm	VLMO30L1M2−GS08
LED2	1	LED, Green, SMD, 2.4 mm, 2 mA, 1.9 V, 575 nm	2.4 mm, 2 mA, 1.9 V, 575 nm	VLMC3100−GS08
C11, C12	2	Capacitor	10 μF	C3216X7R1E106K160AE
R2, R3, R4, R5, R26, R27, R28, R29, R37	9	Resistor	10 Ω	CRCW060310K0FKEA
C1, C2	2	Capacitor	10 pF	C0402C100J5GACTU
SW1, SW2, SW3, SW4	4	Switch	12 V, 50 mA	MCDTS6−3N
X1	1	Crystal Oscillator, 16 MHz, Low Profile SMD, 3.2 mm 2.5 mm, 30 ppm, 12.5 pF, 50 ppm, FA−238 Series	16 MHz to 60 MHz / Load: 12.5 pF / Stability: 30 ppm / Tolerance: 50 ppm	Q22FA23800181 FA−238
R22	1	Resistor	20 Ω	CRCW060320K0FKEA
R10	1	Resistor	27 Ω	352027RJT
U1	1	Transceiver for KNX Twisted Pair Networks	40 pins	NCN5130MNTWG

Table 7. BILL OF MATERIALS UART-VERSION (continued)

Designator	Qty	Description	Value	Part Number
D2	1	SMAJ40CA − TVS Diode, TRANSZORB SMAJ Series, Bidirectional, 40 V, 64.5 V, DO−214AC, 2 Pins	40 V, 400 W	SMAJ40CA
C5	1	Capacitor	47 nF, 50 V	CGA3E2X7R1H473K080AA
C9	1	Capacitor	100 μF, 35 V	EEEFT1V101AP
S1	1	6.0 x 3.8 mm SMD J−Bend WS−TASV	100 mΩ, 250 V (AC)	434 123 025 816
C3, C4	2	Capacitor	100 nF	CC0402KRX7R7BB104
C8	1	Capacitor	100 nF, 50 V	VJ0603Y104KXACW1BC
C7	1	Capacitor	100 nF, 50 V	VJ0603Y104KXACW1BC
R18	1	Resistor	130 Ω	CRCW0603130KFKEA
C6	1	Capacitor	220 nF, 50 V	CGA3E3X7R1H224K080AB
R1, R16, R17, R34	4	Resistor	560 Ω	CRCW0603560RFKEA
LED6	1	Surface Mount Chip LED, Red	0603, Red	KPT−1608EC
R33, R38	2	Resistor	680 Ω	CRCW0603680RFKEA
R14, R35, R36	3	Resistor	750 Ω	CRCW0603750RFKEA
J5	1	Male connector for WAGO 243−211	Pitch: 5.75 mm / Diameter:1 mm / 100 V / 6 A	13.14.125
LED1, LED5	2	LED, Red, 2.4 mm, 636 nm, 1.8 V, 2 mA, 18 mcd	Red, 1.8 V, 2 mA	VLMS30J1L2−GS08
D3	1	Surface Mount Schottky Power Rectifier	Uf = 430 mV, If = 500 mA, Ur = 30 V	MBR0530T1G

SPI-version

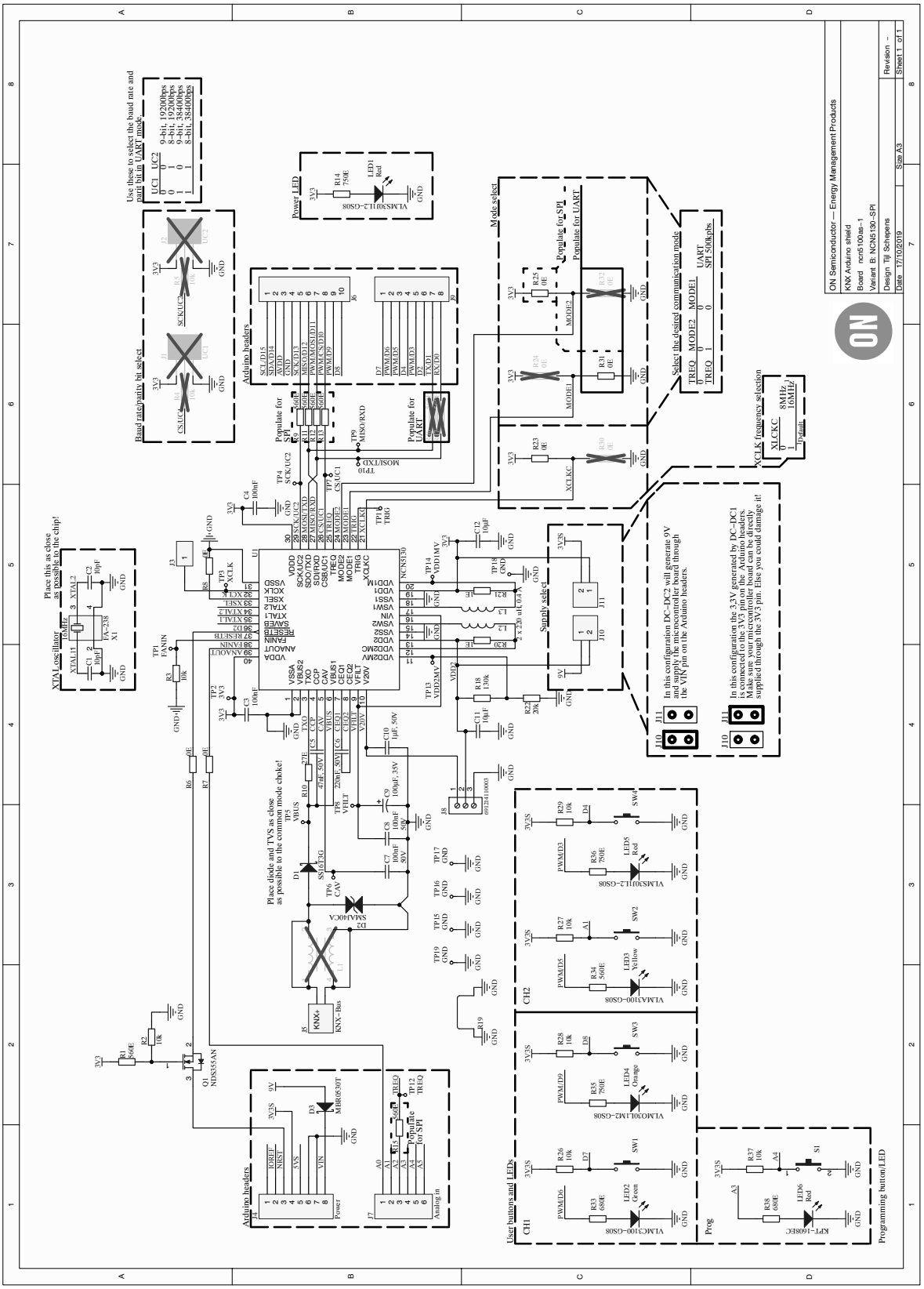

Figure 39. Schematic

Table 8. BILL OF MATERIALS SPI-VERSION

Designator	Qty	Description	Value	Part Number
J3	1	WR−PHD 2.54 mm THT Pin Header, 1p		61300111121
J4	1	Board-To-Board Connector, 2.54 mm, 8 Contacts, Receptacle, Through Hole, 1 Rows		SSQ−110−03−G−S
J6	1	Board-To-Board Connector, 2.54 mm, 10 Contacts, Receptacle, Through Hole, 1 Rows		SSQ−110−03−G−S
J7	1	Board-To-Board Connector, 2.54 mm, 6 Contacts, Receptacle, Through Hole, 1 Rows		SSQ−106−03−G−S
J8	1	Serie 2141 − 3.50 mm Horizontal Entry Modular with Rising Cage Clamp WR−TBL, 3 pin		691214110003
J9	1	Board-To-Board Connector, 2.54 mm, 8 Contacts, Receptacle, Through Hole, 1 Rows		SSQ−108−03−G−S
L2	1	SMT Power Inductor WE−LQFS, size 4828, 220 μH, 0.4 A		74406043221
L3	1	SMT Power Inductor WE−LQFS, size 4828, 220 μH, 0.4 A		74406043221
Q1	1	N-Channel Logic Level Enhancement Mode Field Effect Transistor, 30 V, 1.7 A, −55°C to 150°C, 3-Pin SOT−3, RoHS, Tape and Reel		NDS355AN
J10, J11	2	WR−PHD 2.54 mm THT Pin Header, 2p		
R6, R7, R8, R23, R25, R31	6	Resistor	0 Ω	RC0603JR−070RL
C10	1	Capacitor	1 μF, 50 V	GCM21BR71H105KA03L
D1	1	Schottky Rectifier, Singel 60 V, 1 A, DO−214AC, 2 Pins, 720 mV	1 A / 720 mV / 60 V	SS16T3G
R20, R21	2	Resistor	1 Ω	RC0603FR−071RL
LED3	1	LED, Yellow, SMD, 2 mA, 2.2 V, 594 nm	2 mA, 2.2 V, 594 nm	VLMA3100−GS08
R19	1	2 (1 x 2) Position Shunt Connector Non−Insulated 0.400 in (10.16 mm) Gold	2 pins	D3082−05
LED4	1	LED, Orange, SMD, 2.4 mm, 2 mA, 1.8 V, 609 nm	2.4 mm, 2 mA, 1.8 V, 609 nm	VLMO30L1M2−GS08
LED2	1	LED, Green, SMD, 2.4 mm, 2 mA, 1.9 V, 575 nm	2.4 mm, 2 mA, 1.9 V, 575 nm	VLMC3100−GS08
C11, C12	2	Capacitor	10 μF	C3216X7R1E106K160AE
R2, R3, R26, R27, R28, R29, R37	7	Resistor	10 Ω	CRCW060310K0FKEA
C1, C2	2	Capacitor	10 pF	C0402C100J5GACTU
SW1, SW2, SW3, SW4	4	Switch	12 V, 50 mA	MCDTS6−3N
X1	1	Crystal Oscillator, 16 MHz, Low Profile SMD, 3.2 mm 2.5 mm, 30 ppm, 12.5 pF, 50 ppm, FA−238 Series	16 MHz to 60 MHz / Load: 12.5 pF / Stability: 30 ppm / Tolerance: 50 ppm	Q22FA23800181 FA−238
R22	1	Resistor	20 Ω	CRCW060320K0FKEA
R10	1	Resistor	27 Ω	352027RJT
U1	1	Transceiver for KNX Twisted Pair Networks	40 pins	NCN5130MNTWG
D2	1	SMAJ40CA − TVS Diode, TRANSZORB SMAJ Series, Bidirectional, 40 V, 64.5 V, DO−214AC, 2 Pins	40 V, 400 W	SMAJ40CA
C5	1	Capacitor	47 nF, 50 V	CGA3E2X7R1H473K080AA

Table 8. BILL OF MATERIALS SPI-VERSION (continued)

Designator	Qty	Description	Value	Part Number
C9	1	Capacitor	100 μF, 35 V	EEEFT1V101AP
S1	1	6.0 x 3.8 mm SMD J−Bend WS−TASV	100 mΩ, 250 V (AC)	434 123 025 816
C3, C4	2	Capacitor	100 nF	CC0402KRX7R7BB104
C8	1	Capacitor	100 nF, 50 V	VJ0603Y104KXACW1BC
C7	1	Capacitor	100 nF, 50 V	VJ0603Y104KXACW1BC
R18	1	Resistor	130 Ω	CRCW0603130KFKEA
C6	1	Capacitor	220 nF, 50 V	CGA3E3X7R1H224K080AB
R1, R9, R11, R12, R13, R15, R34	7	Resistor	560 Ω	CRCW0603560RFKEA
LED6	1	Surface Mount Chip LED, Red	0603, Red	KPT−1608EC
R33, R38	2	Resistor	680 Ω	CRCW0603680RFKEA
R14, R35, R36	3	Resistor	750 Ω	CRCW0603750RFKEA
J5	1	Male connector for WAGO 243−211	Pitch: 5.75 mm / Diameter: 1 mm / 100 V / 6 A	13.14.125
LED1, LED5	2	LED, Red, 2.4 mm, 636 nm, 1.8 V, 2 mA, 18 mcd	Red, 1.8 V, 2 mA	VLMS30J1L2−GS08
D3	1	Surface Mount Schottky Power Rectifier	Uf = 430 mV, If = 500 mA, Ur = 30 V	MBR0530T1G

APPENDIX E – NCN5121ASGEVB

UART-version

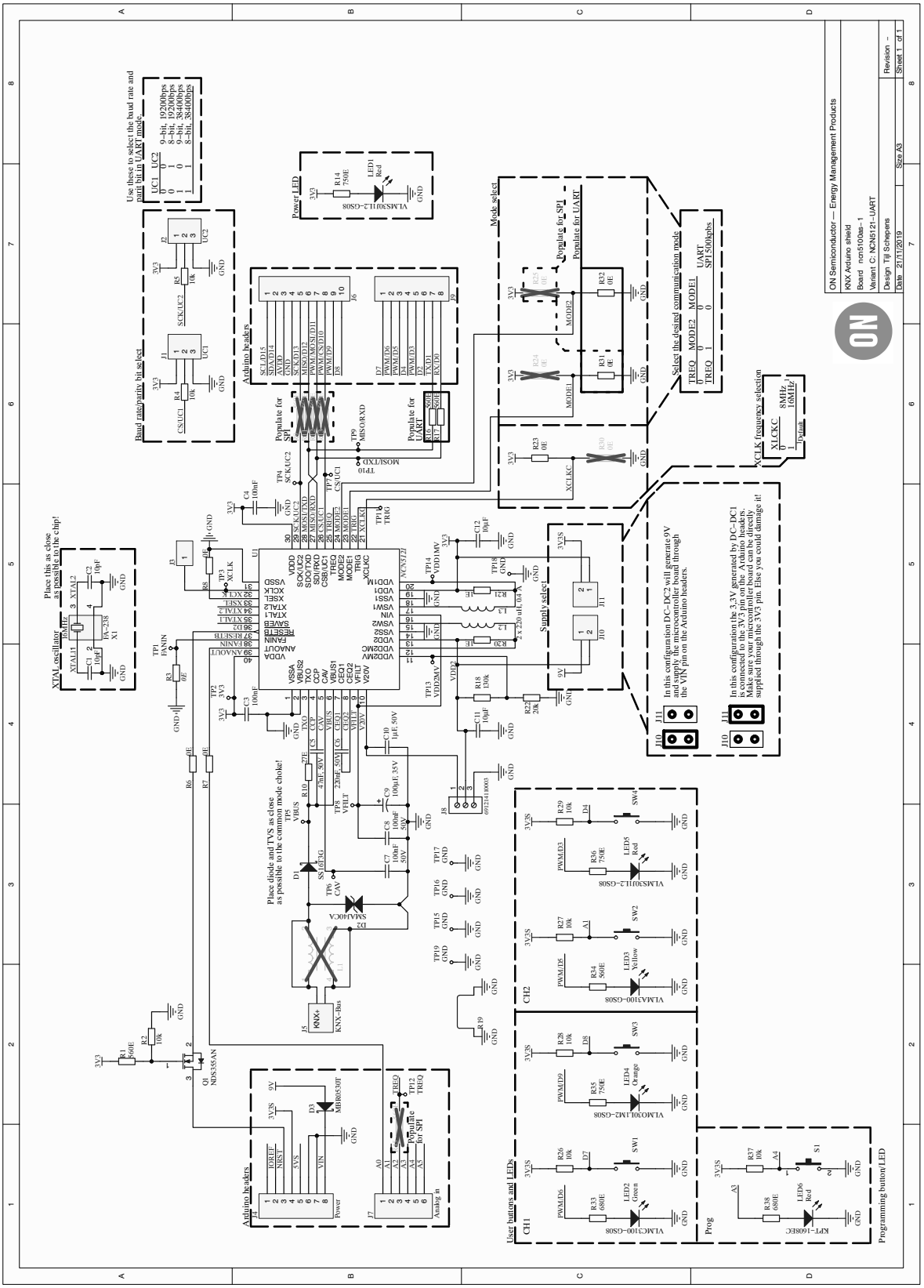

Figure 40. Schematic

Table 9. BILL OF MATERIALS UART-VERSION

Designator	Qty	Description	Value	Part Number
J1	1	WR−PHD 2.54 mm THT Pin Header, 3p		61300311121
J2	1	WR−PHD 2.54 mm THT Pin Header, 3p		61300311121
J3	1	WR−PHD 2.54 mm THT Pin Header, 1p		61300111121
J4	1	Board-To-Board Connector, 2.54 mm, 8 Contacts, Receptacle, Through Hole, 1 Rows		SSQ−110−03−G−S
J6	1	Board-To-Board Connector, 2.54 mm, 10 Contacts, Receptacle, Through Hole, 1 Rows		SSQ−110−03−G−S
J7	1	Board-To-Board Connector, 2.54 mm, 6 Contacts, Receptacle, Through Hole, 1 Rows		SSQ−106−03−G−S
J8	1	Serie 2141 − 3.50 mm Horizontal Entry Modular with Rising Cage Clamp WR−TBL, 3 pin		691214110003
J9	1	Board-To-Board Connector, 2.54 mm, 8 Contacts, Receptacle, Through Hole, 1 Rows		SSQ−108−03−G−S
L2	1	SMT Power Inductor WE−LQFS, size 4828, 220 μH, 0.4 A		74406043221
L3	1	SMT Power Inductor WE−LQFS, size 4828, 220 μH, 0.4 A		74406043221
Q1	1	N-Channel Logic Level Enhancement Mode Field Effect Transistor, 30 V, 1.7 A, −55°C to 150°C, 3-Pin SOT−3, RoHS, Tape and Reel		NDS355AN
J10, J11	2	WR−PHD 2.54 mm THT Pin Header, 2p		
R3, R6, R7, R8, R23, R31, R32	7	Resistor	0 Ω	CRCW06030000Z0EA, RC0603JR−070RL
C10	1	Capacitor	1 μF, 50 V	GCM21BR71H105KA03L
D1	1	Schottky Rectifier, Singel 60 V, 1 A, DO−214AC, 2 Pins, 720 mV	1 A / 720 mV / 60 V	SS16T3G
R20, R21	2	Resistor	1 Ω	RC0603FR−071RL
LED3	1	LED, Yellow, SMD, 2 mA, 2.2 V, 594 nm	2 mA, 2.2 V, 594 nm	VLMA3100−GS08
R19	1	2 (1 x 2) Position Shunt Connector Non-Insulated 0.400 in (10.16 mm) Gold	2 pins	D3082−05
LED4	1	LED, Orange, SMD, 2.4 mm, 2 mA, 1.8 V, 609 nm	2.4 mm, 2 mA, 1.8 V, 609 nm	VLMO30L1M2−GS08
LED2	1	LED, Green, SMD, 2.4 mm, 2 mA, 1.9 V, 575 nm	2.4 mm, 2 mA, 1.9 V, 575 nm	VLMC3100−GS08
C11, C12	2	Capacitor	10 μF	C3216X7R1E106K160AE
R2, R4, R5, R26, R27, R28, R29, R37	8	Resistor	10 Ω	CRCW060310K0FKEA
C1, C2	2	Capacitor	10 pF	C0402C100J5GACTU
SW1, SW2, SW3, SW4	4	Switch	12 V, 50 mA	MCDTS6−3N
X1	1		16 MHz to 60 MHz / Load: 12.5 pF / Stability: 30 ppm / Tolerance: 50 ppm	Q22FA23800181 FA−238
R22	1	Resistor	20 Ω	CRCW060320K0FKEA
R10	1	Resistor	27 Ω	352027RJT
U1	1	Transceiver for KNX Twisted Pair Networks	40 pins	NCN5121MNTWG

Table 9. BILL OF MATERIALS UART-VERSION (continued)

Designator	Qty	Description	Value	Part Number
D2	1	SMAJ40CA − TVS Diode, TRANSZORB SMAJ Series, Bidirectional, 40 V, 64.5 V, DO−214AC, 2 Pins	40 V, 400 W	SMAJ40CA
C5	1	Capacitor	47 nF, 50 V	CGA3E2X7R1H473K080AA
C9	1	Capacitor	100 μF, 35 V	EEEFT1V101AP
S1	1	6.0 x 3.8 mm SMD J−Bend WS−TASV	100 mΩ, 250 V (AC)	434 123 025 816
C3, C4	2	Capacitor	100 nF	CC0402KRX7R7BB104
C8	1	Capacitor	100 nF, 50 V	VJ0603Y104KXACW1BC
C7	1	Capacitor	100 nF, 50 V	VJ0603Y104KXACW1BC
R18	1	Resistor	130 Ω	CRCW0603130KFKEA
C6	1	Capacitor	220 nF, 50 V	CGA3E3X7R1H224K080AB
R1, R16, R17, R34	4	Resistor	560 Ω	CRCW0603560RFKEA
LED6	1	Surface Mount Chip LED, Red	0603, Red	KPT−1608EC
R33, R38	2	Resistor	680 Ω	CRCW0603680RFKEA
R14, R35, R36	3	Resistor	750 Ω	CRCW0603750RFKEA
J5	1	Male connector for WAGO 243−211	Pitch: 5.75 mm / Diameter: 1 mm / 100 V / 6 A	13.14.125
LED1, LED5	2	LED, Red, 2.4 mm, 636 nm, 1.8 V, 2 mA, 18 mcd	Red, 1.8 V, 2 mA	VLMS30J1L2−GS08
D3	1	Surface Mount Schottky Power Rectifier	Uf = 430 mV, If = 500 mA, Ur = 30 V	MBR0530T1G

SPI-version

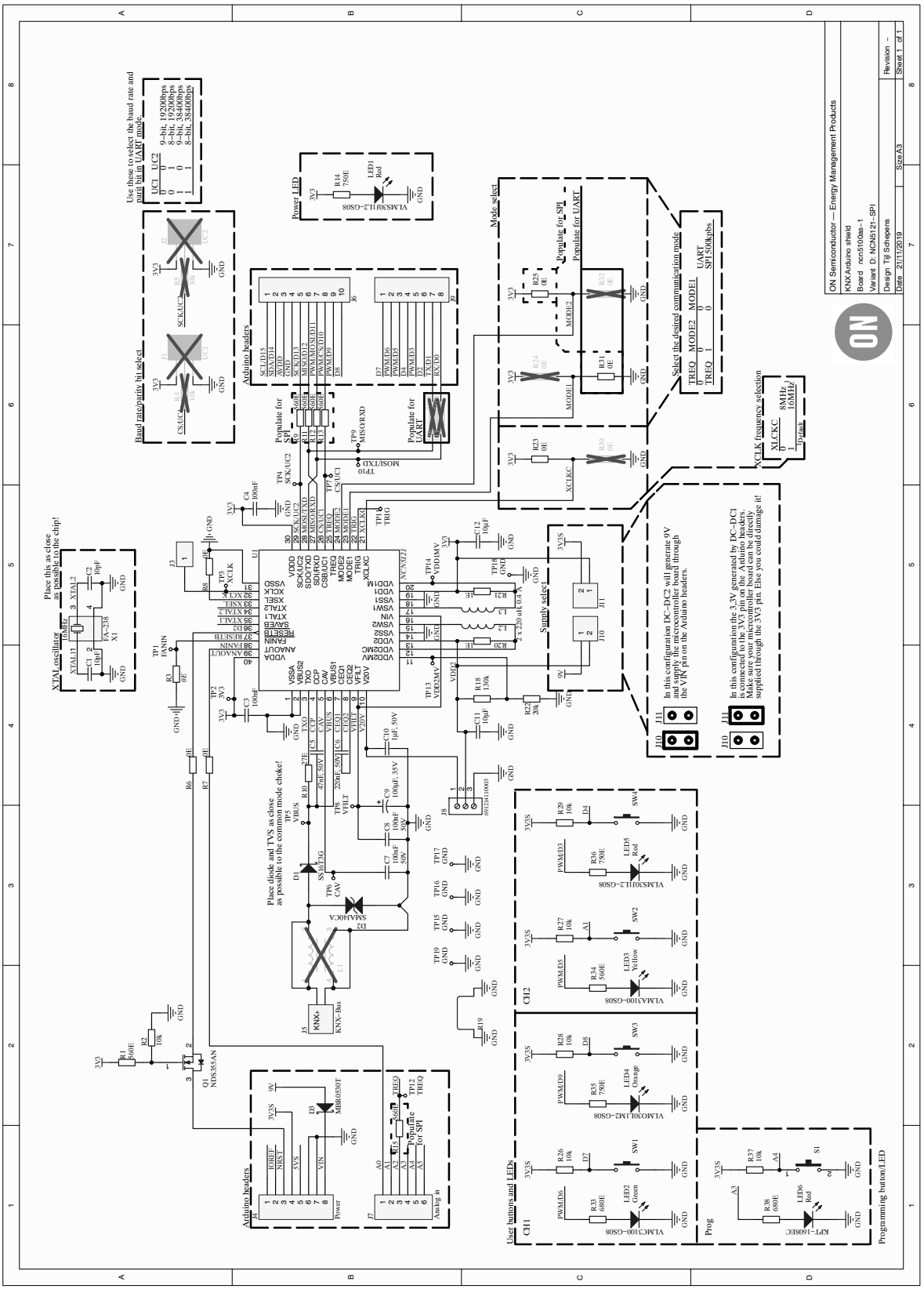

Figure 41. Schematic

Table 10. BILL OF MATERIALS SPI-VERSION

Designator	Qty	Description	Value	Part Number
J3	1	WR−PHD 2.54 mm THT Pin Header, 1p		61300111121
J4	1	Board-To-Board Connector, 2.54 mm, 8 Contacts, Receptacle, Through Hole, 1 Rows		SSQ−110−03−G−S
J6	1	Board-To-Board Connector, 2.54 mm, 10 Contacts, Receptacle, Through Hole, 1 Rows		SSQ−110−03−G−S
J7	1	Board-To-Board Connector, 2.54 mm, 6 Contacts, Receptacle, Through Hole, 1 Rows		SSQ−106−03−G−S
J8	1	Serie 2141 − 3.50 mm Horizontal Entry Modular with Rising Cage Clamp WR−TBL, 3 pin		691214110003
J9	1	Board-To-Board Connector, 2.54 mm, 8 Contacts, Receptacle, Through Hole, 1 Rows		SSQ−108−03−G−S
L2	1	SMT Power Inductor WE−LQFS, size 4828, 220 μH, 0.4 A		74406043221
L3	1	SMT Power Inductor WE−LQFS, size 4828, 220 μH, 0.4 A		74406043221
Q1	1	N−Channel Logic Level Enhancement Mode Field Effect Transistor, 30 V, 1.7 A, −55°C to 150°C, 3-Pin SOT−3, RoHS, Tape and Reel		NDS355AN
J10, J11	2	WR−PHD 2.54 mm THT Pin Header,		
R3, R6, R7, R8, R23, R25, R31	7	Resistor	0 Ω	CRCW06030000Z0EA, RC0603JR−070RL
C10	1	Capacitor	1 μF, 50 V	GCM21BR71H105KA03L
D1	1	Schottky Rectifier, Singel 60 V, 1 A, DO−214AC, 2 Pins, 720 mV	1 A / 720 mV / 60 V	SS16T3G
R20, R21	2	Resistor	1 Ω	RC0603FR−071RL
LED3	1	LED, Yellow, SMD, 2 mA, 2.2 V, 594 nm	2 mA, 2.2 V, 594 nm	VLMA3100−GS08
R19	1	2 (1 x 2) Position Shunt Connector Non-Insulated 0.400in (10.16 mm) Gold	2 pins	D3082−05
LED4	1	LED, Orange, SMD, 2.4 mm, 2 mA, 1.8 V, 609 nm	2.4 mm, 2 mA, 1.8 V, 609 nm	VLMO30L1M2−GS08
LED2	1	LED, Green, SMD, 2.4 mm, 2 mA, 1.9 V, 575 nm	2.4 mm, 2 mA, 1.9 V, 575 nm	VLMC3100−GS08
C11, C12	2	Capacitor	10 μF	C3216X7R1E106K160AE
R2, R26, R27, R28, R29, R37	6	Resistor	10 Ω	CRCW060310K0FKEA
C1, C2	2	Capacitor	10 pF	C0402C100J5GACTU
SW1, SW2, SW3,	4	Switch	12 V, 50 mA	MCDTS6−3N
SW4 X1	1		16 MHz to 60 Mhz / Load: 12.5 pF / Stability: 30 ppm / Tolerance: 50 ppm	Q22FA23800181 FA−238
R22	1	Resistor	20 Ω	CRCW060320K0FKEA
R10	1	Resistor	27 Ω	352027RJT
U1	1	Transceiver for KNX Twisted Pair Networks	40pins	NCN5121MNTWG
D2	1	SMAJ40CA − TVS Diode, TRANSZORB SMAJ Series, Bidirectional, 40 V, 64.5 V, DO−214AC, 2 Pins	40 V, 400 W	SMAJ40CA
C5	1	Capacitor	47 nF, 50 V	CGA3E2X7R1H473K080AA

Table 10. BILL OF MATERIALS SPI-VERSION (continued)

Designator	Qty	Description	Value	Part Number
C9	1	Capacitor	100 μF, 35 V	EEEFT1V101AP
S1	1	6.0 x 3.8 mm SMD J−Bend WS−TASV	100 mΩ, 250 V (AC)	434 123 025 816
C3, C4	2	Capacitor	100 nF	CC0402KRX7R7BB104
C8	1	Capacitor	100 nF, 50 V	VJ0603Y104KXACW1BC
C7	1	Capacitor	100 nF, 50 V	VJ0603Y104KXACW1BC
R18	1	Resistor	130 Ω	CRCW0603130KFKEA
C6	1	Capacitor	220 nF, 50 V	CGA3E3X7R1H224K080AB
R1, R9, R11, R12, R13, R15, R34	7	Resistor	560 Ω	CRCW0603560RFKEA
LED6	1	Surface Mount Chip LED, Red	0603, Red	KPT−1608EC
R33, R38	2	Resistor	680 Ω	CRCW0603680RFKEA
R14, R35, R36	3	Resistor	750 Ω	CRCW0603750RFKEA
J5	1	Male connector for WAGO 243−211	Pitch: 5.75 mm / Diameter: 1 mm / 100 V / 6 A	13.14.125
LED1, LED5	2	LED, Red, 2.4 mm, 636 nm, 1.8 V, 2 mA, 18 mcd	Red, 1.8 V, 2 mA	VLMS30J1L2−GS08
D3	1	Surface Mount Schottky Power Rectifier	Uf = 430 mV, If = 500 mA, Ur = 30 V	MBR0530T1G

APPENDIX F – NCN5110ASGEVB SCHEMATIC (FULL OPTION)

Full Option

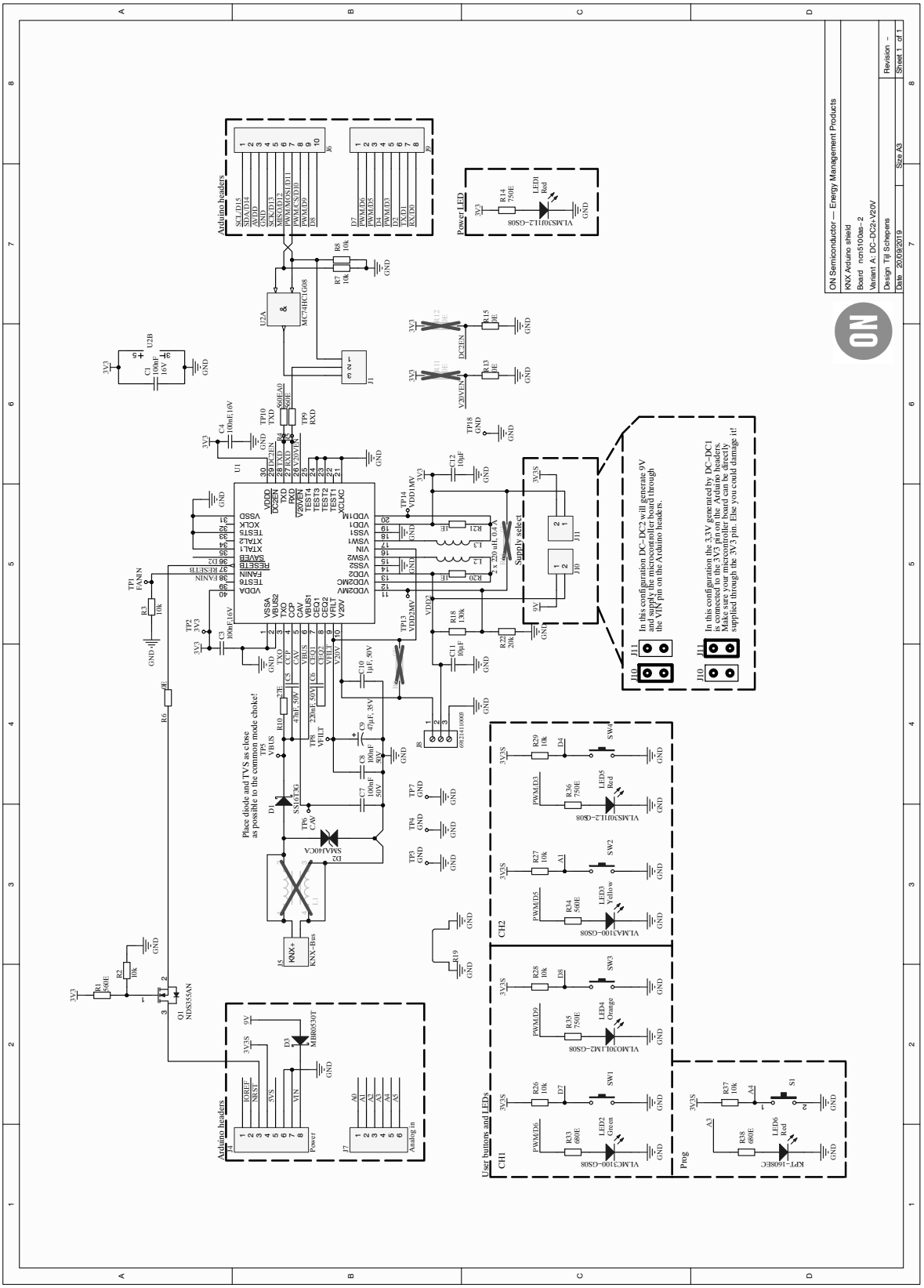

Figure 42. Schematic

Table 11. BILL OF MATERIALS FULL VERSION

Designator	Qty	Description	Value	Part Number
J1	1	WR−PHD 2.54 mm THT Pin Header, 03p		61300311121
J4	1	Board-To-Board Connector, 2.54 mm, 8 Contacts, Receptacle, Through Hole, 1 Rows		SSQ−110−03−G−S
J6	1	Board-To-Board Connector, 2.54 mm, 10 Contacts, Receptacle, Through Hole, 1 Rows		SSQ−110−03−G−S
J7	1	Board-To-Board Connector, 2.54 mm, 6 Contacts, Receptacle, Through Hole, 1 Rows		SSQ−106−03−G−S
J8	1	Serie 2141 − 3.50 mm Horizontal Entry Modular with Rising Cage Clamp WR−TBL, 3 pin		
J9	1	Board-To-Board Connector, 2.54 mm, 8 Contacts, Receptacle, Through Hole, 1 Rows		SSQ−108−03−G−S
L2	1	SMT Power Inductor WE−LQFS, size 4828, 220 μH, 0.4 A		
L3	1	SMT Power Inductor WE−LQFS, size 4828, 220 μH, 0.4 A		
Q1	1	N-Channel Logic Level Enhancement Mode Field Effect Transistor, 30 V, 1.7 A, −55°C to 150°C, 3-Pin SOT−3, RoHS, Tape and Reel		
U2	1	Single 2-Input AND Gate		MC74HC1G08DTT1G
J10, J11	2	WR−PHD 2.54 mm THT Pin Header, 2p		
R6, R13, R15	3	Resistor	0 Ω	
C10	1	Capacitor	1 μF, 50 V	
D1	1	Schottky Rectifier, Singel 60 V, 1 A,	1 A / 720 mV / 60 V	SS16T3G
R20, R21	2	Resistor	1 Ω	
LED3	1	LED, Yellow, SMD, 2 mA, 2.2 V, 594 nm	2 mA, 2.2 V, 594 nm	VLMA3100−GS08
R19	1	2 (1 x 2) Position Shunt Connector	2 pins	D3082−05
LED4	1	LED, Orange, SMD, 2.4 mm, 2 mA, 1.8 V, 609 nm	2.4 mm, 2 mA, 1.8 V, 609 nm	VLMO30L1M2−GS08
LED2	1	LED, Green, SMD, 2.4 mm, 2 mA, 1.9 V, 575 nm	2.4 mm, 2 mA, 1.9 V, 575 nm	VLMC3100−GS08
C11, C12	2	Capacitor	10 μF	
R2, R3, R7, R8, R26, R27, R28, R29, R37	9	Resistor	10 Ω	
SW1, SW2, SW3, SW4	4	Switch	12 V, 50 mA	MCDTS6−3N
R22	1	Resistor	20 Ω	
R10	1	Resistor	27 Ω	
U1	1	Transceiver for KNX Twisted Pair Networks	40 pins	NCN5110
D2	1	SMAJ40CA − TVS Diode, TRANSZORB SMAJ Series, Bidirectional, 40 V, 64.5 V, DO−214AC, 2 Pins	40 V, 400 W	SMAJ40CA
C9	1	Capacitor	47 μF, 35 V	
C5	1	Capacitor	47 nF, 50 V	
S1	1	6.0 x 3.8 mm SMD J−Bend WS−TASV	100 mΩ, 250 V (AC)	434 123 025 816
C3, C4	2	Capacitor	100 nF, 16 V	

Table 11. BILL OF MATERIALS FULL VERSION (continued)

Designator	Qty	Description	Value	Part Number
C8	1	Capacitor	100 nF, 50 V	
C1	1	Capacitor	100 nF, 16 V	
C7	1	Capacitor	100 nF, 50 V	
R18	1	Resistor	130 Ω	
C6	1	Capacitor	220 nF, 50 V	
R1, R4, R5, R34	4	Resistor	560 Ω	
LED6	1	Surface Mount Chip LED, Red	0603, Red	KPT−1608EC
R33, R38	2	Resistor	680 Ω	
R14, R35, R36	3	Resistor	750 Ω	
LED1, LED5	2	LED, Red, 2.4 mm, 636 nm, 1.8 V, 2 mA, 18 mcd	Led, Red, 1.8 V, 2 mA	VLMS30J1L2−GS08
J5	1	Male connector for WAGO 243−211	Pitch: 5.75 mm / Diameter: 1 mm / 100 V / 6 A	243−211Male
D3	1	Surface Mount Schottky Power Rectifier	Uf = 430 mV, If = 500 mA, Ur = 30 V	MBR0530T1G

Minimal BoM Version

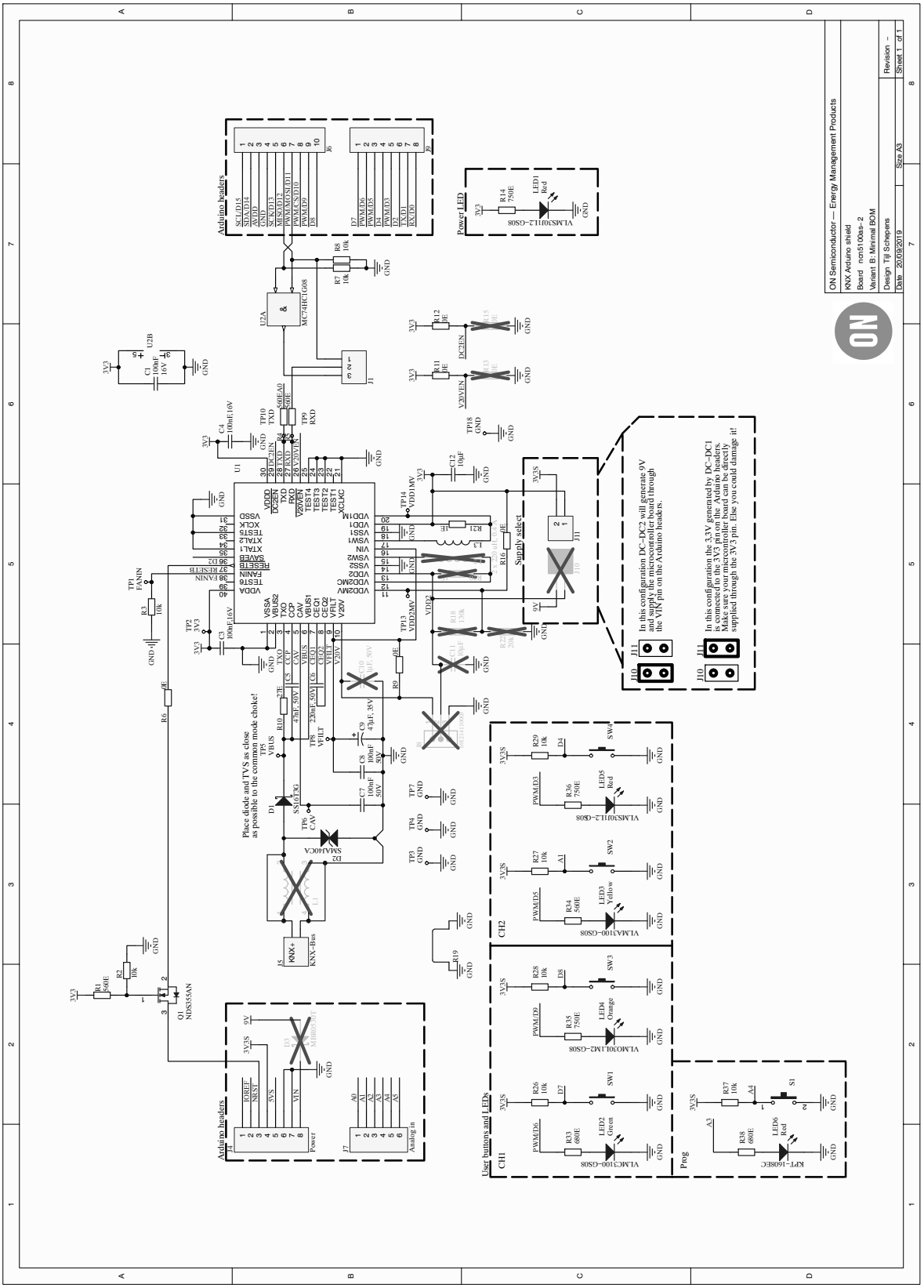

Figure 43. Schematic

Table 12. BILL OF MATERIALS minimal BOM VERSION

Designator	Qty	Description	Value	Part Number
J1	1	WR−PHD 2.54 mm THT Pin Header, 03p		61300311121
J4	1	Board-To-Board Connector, 2.54 mm, 8 Contacts, Receptacle, Through Hole, 1 Rows		SSQ−110−03−G−S
J6	1	Board-To-Board Connector, 2.54 mm, 10 Contacts, Receptacle, Through Hole, 1 Rows		SSQ−110−03−G−S
J7	1	Board-To-Board Connector, 2.54 mm, 6 Contacts, Receptacle, Through Hole, 1 Rows		SSQ−106−03−G−S
J9	1	Board-To-Board Connector, 2.54 mm, 8 Contacts, Receptacle, Through Hole, 1 Rows		SSQ−108−03−G−S
J11	1	WR−PHD 2.54 mm THT Pin Header, 2p		
L3	1	SMT Power Inductor WE−LQFS, size 4828, 220 μH, 0.4 A		
Q1	1	N-Channel Logic Level Enhancement Mode Field Effect Transistor, 30 V, 1.7 A, −55°C, 3-Pin SOT−3, RoHS, Tape and Reel		
U2	1	Single 2−Input AND Gate		MC74HC1G08DTT1G
R6, R9, R11, R12, R16	5	Resistor	0 Ω	
D1	1	Schottky Rectifier, Single 60 V, 1 A, DO−214AC, 2 Pins, 720 mV	1 A / 720 mV / 60 V	SS16T3G
R21	1	Resistor	1 Ω	
LED3	1	LED, Yellow, SMD, 2 mA, 2.2 V, 594 nm	2 mA, 2.2 V, 594 nm	VLMA3100−GS08
R19	1	2 (1 x 2) Position Shunt Connector Non-Insulated 0.400in (10.16 mm) Gold	2 pins	D3082−05
LED4	1	LED, Orange, SMD, 2.4 mm, 2 mA, 1.8 V, 609 nm	2.4 mm, 2 mA, 1.8 V, 609 nm	VLMO30L1M2−GS08
LED2	1	LED, Green, SMD, 2.4 mm, 2 mA, 1.9 V, 575 nm	2.4 mm, 2 mA, 1.9 V, 575 nm	VLMC3100−GS08
C12	1	Capacitor	10 μF	
R2, R3, R7, R8, R26, R27, R28, R29, R37	9	Resistor	10 Ω	
	4	Switch	12 V, 50 mA	MCDTS6−3N
R10	1	Resistor	27 Ω	
U1	1	Transceiver for KNX Twisted Pair Networks	40 pins	NCN5110
D2	1	SMAJ40CA − TVS Diode, TRANSZORB SMAJ Series, Bidirectional, 40 V, 64.5 V, DO−214AC, 2 Pins	40 V, 400 W	SMAJ40CA
C9	1	Capacitor	47 μF, 35 V	
C5	1	Capacitor	47 nF, 50 V	
S1	1	6.0 x 3.8 mm SMD J−Bend WS−TASV	100 mΩ, 250 V (AC)	434 123 025 816
C3, C4	2	Capacitor	100 nF, 16 V	
C8	1	Capacitor	100 nF, 50 V	
C1	1	Capacitor	100 nF, 16 V	
C7	1	Capacitor	100 nF, 50 V	
C6	1	Capacitor	220 nF, 50 V	
R1, R4, R5, R34	4	Resistor	560 Ω	

Table 12. BILL OF MATERIALS minimal BOM VERSION (continued)

Designator	Qty	Description	Value	Part Number
LED6	1	Surface Mount Chip LED, Red	0603, Red	KPT−1608EC
R33, R38	2	Resistor	680 Ω	
R14, R35, R36	3	Resistor	750 Ω	
LED1, LED5	2	LED, Red, 2.4 mm, 636 nm, 1.8 V, 2 mA, 18 mcd	Led, Red, 1.8 V, 2 mA	VLMS30J1L2−GS08
J5	1	Male connector for WAGO 243−211	Pitch: 5.75 mm / Diameter: 1 mm / 100 V / 6 A	243−211Male

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