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KNX Fan-In

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APPLICATION NOTE

INTRODUCTION

The NCN5100 transceiver family is suitable for use in KNX twisted pair networks. They enable the development of a wide variety of applications for use in home and building automation.

All the transceivers generate—from the unregulated bus voltage—stabilized voltages to power itself and external circuitry. Thanks to the high current capability of the NCN5110 and NCN5130 they are able to supply very demanding applications using displays, speakers,...

The KNX standard [2] specifies rules for the current consumption of a device. The transceiver must be configured correctly to meet the specification. Here the KNX Fan−in−Model is explained and is shown how to apply it to the NCN5100 transceivers.

BUS CURRENT CONSUMPTION

There are two aspects when it comes to the current consumption of a KNX−device. First is the maximum current a device consumes. It must be limited to a certain level which is specified in its datasheet. This is called the Fan−in−Model.

The second aspect is how the current changes on the bus. A KNX−device is not allowed to instantaneously change its current consumption as seen from the bus. The KNX standard [4] specifies at which rate it can change. This is called Power Conversion or Load Changes.

It is very important that both aspects are taken into account during the design of a KNX−application.

Fan−In−Model

Every device in a KNX−network draws current from the bus. The current draw depends on the application and the operating conditions. According to the KNX standard [3] (section 2.5.4), the current draw should be limited to the real need.

The maximum power consumption of the device must be specified in its datasheet and is added to the KNX−database of the product. This power consumption is specified according to the Fan−in−Model.

In a KNX−network it is very important that the maximum amount of devices per segment is not exceeded. Exceeding the limit can lead to communication issues and other unwanted effects. The Fan−in−Model can be used to determine the maximum allowed number of devices connected to one physical segment and the required power supply.

To determine the power consumption that must be listed in the device datasheet, measure the maximum current consumption at the nominal bus voltage of 24 V. Then take the next higher value listed in Table 1.

Table 1. FAN−IN−MODEL CURRENT CLASSES

Current Class
2.5 mA
5 mA
7.5 mA
10 mA
12.5 mA
15 mA
17.5 mA
20 mA
25 mA
30 mA
35 mA
Continue in steps of 5 mA

This is the value that must be listed in the datasheet and is added to the KNX−database.

Now when building the network this value is used to determine the maximum number of devices per physical segment. There are two conditions which must be met at the same time.

First the total current consumption of all devices connected to the segment, shall not exceed the nominal output current of the power supply. The following equation can be used to dimension the power supply:

$$\sum_{n=1}^{N} I_{c(n)} < I_N \qquad \text{(eq. 1)}$$

Where N is the number of connected devices, I_C is the current class of the device taken from Table 1 and I_N is the nominal output current of the power supply.

Secondly the transmission characteristics of the devices must be respected. The following condition must be met:

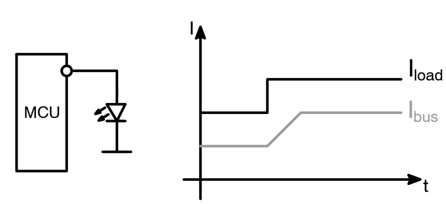

Figure 1. A Load Change in the Application

$$\sum_{n=1}^{N} W_{t(n)} < 257 \quad \text{(eq. 2)}$$

W_t is 1 for a TP1−256 device and 4 for a TP1−64 device. If it is not specified if the device is TP1−64 or TP1−256, $W_t = 4$ is taken by default.

Load Changes

When the application switches on an LED (or any other load) as in Figure 1, instantaneously more current is drawn from the power supply. For the NCN5100 transceivers this can be DC−DC1, DC−DC2 or V20V. The KNX standard [4] (section 4.4.3, Table 4, repeated in Appendix A) specifies that the bus current slope must be limited to 0.5 mA/ms for a fan−in of 10 mA (see section Fan−In−Model).

As the instantaneous current cannot come from the bus, it must come from somewhere else. In this case it will come from the Vfilt buffer capacitor. The transceivers bus coupler will then charge the buffer capacitor again, at a rate of 0.5 mA/ms.

More demanding applications will require a larger buffer capacitor to handle the larger load changes. The KNX standard [4] (section 3.3 Important notes) specifies that when the fan−in model is increased, the maximum allowed current slope scales accordingly. This allows the bus coupler to charge the buffer capacitor faster.

Setting the maximum current drawn by the bus coupler and the associated current slopes, is done through the FANIN−pin on the NCN5100 transceivers.

Selecting both the right Vfilt capacitor and fanin resistor are very important for the application to function correctly.

VFILT DIMENSIONING

The selection of the right Vfilt capacitor is very important for the correct operation of the application. A too small buffer capacitor can lead to a POR−event at heavy load changes, while a too large capacitor can lead to excessively long start−up times.

To dimension the capacitor, there are four criteria. First the KNX standard [4] (4.3 Power Conversion (Switch On/Off Slow)) specifies that the total start−up time of the system must be below 10 s. This time is comprised of the time to charge the buffer capacitor to 12 V (where the DC−DC converter becomes operational) and the start−up time of the rest of the system[1] $t_{startup,system}$. The following formula, found in the transceiver datasheet, gives the upper limit for the Vfilt capacitor:

$$C < \left(t_{startup,max} - t_{startup,system}\right) \cdot \frac{I_{coupler\_lim,startup}}{V_{FILTH}} \quad \text{(eq. 3)}$$

Worst case scenario:

$$C < \left(10\ s - t_{startup,system}\right) \cdot \frac{I_{coupler\_lim,startup}}{11.2\ V} \quad \text{(eq. 4)}$$

The bus current limit at start−up can be much higher than during normal operation to charge the buffer capacitor. For a fan−in of 10 mA the start−up current limit can be up to 30 mA [4] (4.2 Power Conversion (Switch On Fast)). Again this current limit scales linearly with the fan−in setting.

The second criteria is the capability to filter out load steps. As discussed in section *Load Changes* the Vfilt capacitor must be large enough to deliver the instantaneous current during load changes. The following formula calculates the minimum value to handle the specified load steps:

$$C > \frac{\Delta I^2_{step}}{2 \cdot \left(V_{BUS1} - V_{coupler\_drop} - V_{FILTL}\right) \cdot \frac{\Delta I_{coupler}}{\Delta t}} \quad \text{(eq. 5)}$$

Worst case scenario:

$$C > \frac{\Delta I^2_{step}}{2 \cdot \left(20\ V - V_{coupler\_drop} - 9.4\ V\right) \cdot \frac{\Delta I_{coupler}}{\Delta t}} \quad \text{(eq. 6)}$$

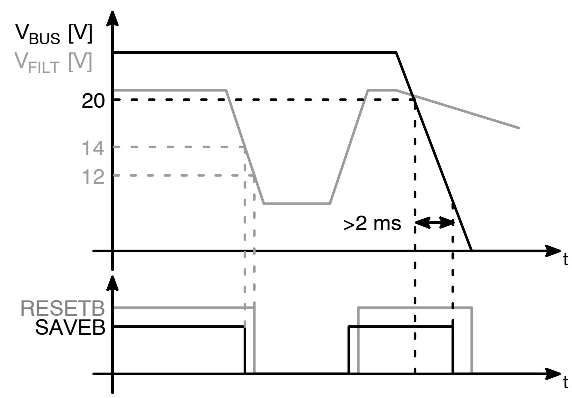

Figure 2. Behavior of the RESETB− and SAVEB−signal

When the bus voltage is disconnected, a KNX−device stores some data to non−volatile memory. The NCN5100 transceiver indicates the MCU that the bus voltage is dropping through the SAVEB−signal. This signal goes low when V_{filt} goes below 14 V followed by RESETB when V_{filt} goes below 12 V as shown in Figure 2. It also goes low when V_{BUS} goes below 20 V for at least 2 ms.

To have enough time to write away all necessary data, the buffer capacitor must be large enough. This formula can be used to calculate the minimum value for Vfilt to reach a certain $t_{warning}$ time:

$$C > I_{system} \cdot \frac{t_{warning} + t_{bus\ filter}}{V_{BUS1} - V_{coupler\_drop} - V_{FILTL}} \quad \text{(eq. 7)}$$

Worst case scenario:

$$C > I_{system} \cdot \frac{t_{warning} + 2\ ms}{20\ V - V_{coupler\_drop} - 9.4\ V} \quad \text{(eq. 8)}$$

1 The device is normally operational after execution of U_{reset}.

As a last requirement, the value of the buffer capacitor must be between 12.5 μF to 4000 μF in order to guarantee proper operation of the transceiver.

The Vfilt capacitor is also responsible for delivering the power during the communication. When the devices start to communicate with each other, the bus voltage drops to transmit a zero. This causes all other transceivers to stop taking current from the bus. Otherwise this could influence the communication. During the complete transmission of the frame the current must come from the Vfilt capacitor. After the frame transmission the capacitor is recharged by the transceiver.

In networks with long cable lengths and clusters of devices, an insufficiently large buffer capacitor can lead to bus voltage drops. This because many devices suddenly draw current to recharge the capacitor, leading to voltage drops across the KNX cable. These drops can disrupt the communication on the bus. For more information refer to section *Bus voltage drops*.

To avoid these issues, the Vfilt capacitor must be dimensioned correctly. Rounding up the calculated capacitor value is important to avoid selecting a too low value.

DIMENSIONING THE FAN−IN RESISTOR

All the NCN5100 transceivers have a FANIN−pin. Depending on the setting of this pin, the bus coupler will limit its current draw from the bus to a certain level. Also the current slopes are adapted to the selected fan−in setting. This ensures that the device is always within the specifications without intervention of the microcontroller.

NCN5121

The NCN5121 has only two fan−in settings. When the FANIN−pin is left floating, the NCN5121 will comply with the Fan−in−Model of 10 mA. During normal operation the current will be limited to 12.0 mA ($I_{coupler\_lim}$) and will change at a rate of 0.5 mA/ms ($\Delta Icoupler / \Delta t$) maximum. When the device starts−up the current will never go above 30 mA ($I_{coupler\_lim,startup}$).

Figure 3 shows the start−up and normal behaviour of a device with a Fan−in−Model of 10 mA. The grey shaded zone indicates the limits specified in the KNX standard.

Tying the FANIN−pin to ground, makes the NCN5121 comply with the 20 mA Fan−in−Model. The current is limited to 24 mA now and will change with a slope of 1 mA/ms. During start−up the current is limited to 60 mA. All the limits are shown in Figure 4.

For the NCN5121 these are the only Fan−in−Models which are supported. To have maximum flexibility when choosing the Fan−in−Model, the NCN5110/NCN5130 should be used.

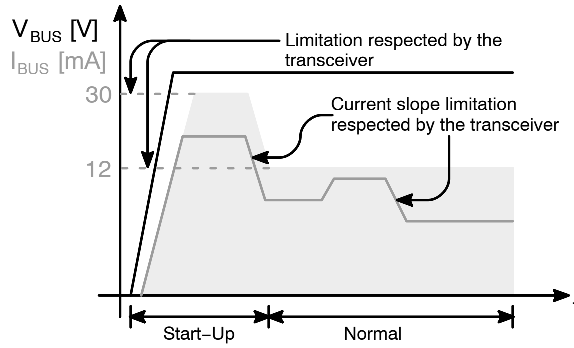

Figure 3. Bus Current for a 10 mA Fan−in−Model

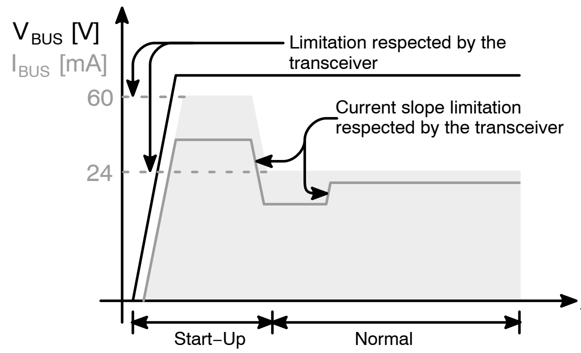

Figure 4. Bus Current for a 20 mA Fan−in−Model

NCN5110/NCN5130

The NCN5110 and NCN5130 support the same FANIN−pin configurations as the NCN5121. On top of that they have a way to select any desired Fan−in−Model from 5 mA to 40 mA.

Selecting the Fan−in−Model is done in an analog way, by connecting a resistance between 10 kΩ and 93.1 kΩ to the FANIN−pin. To calculate what current limit the bus coupler will enforce, the following formula can be used:

$$I_{coupler\_lim} = 4 \times 10^{-4} + \frac{434}{R_{FANIN}} \text{ A} \qquad \text{(eq. 9)}$$

It is recommended to use one of the resistance values listed in Table 2, as these values are preselected to comply with a certain Fan−in−Model. All the relevant characteristics for these resistor values are also listed in the transceivers datasheet.

It is allowed to use other values to comply with any of the current classes listed in Table 1. Always choose the next higher available resistor value when calculating the required resistor value. Measuring if the bus coupler complies with the selected current class is recommended. This is not necessary for resistor values listed in Table 2.

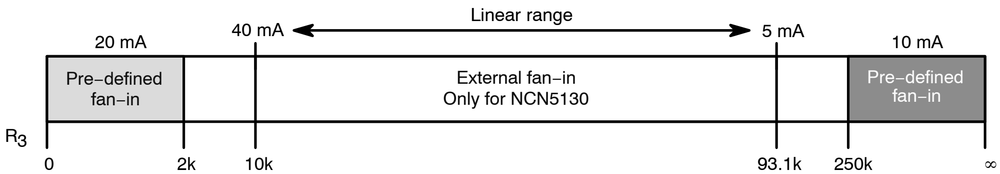

Figure 5. The Different Fan−in Settings

Table 2. RECOMMENDED FAN−IN RESISTOR VALUES

R_3	$I_{coupler\_lim}$ (Typical Values)	Current Class*
∞	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

*According to the fan−in−model [3].

POSSIBLE ISSUES

Some issues seen in a KNX−network are introduced when not all of the aspects above are considered during the design of the device.

Bus Voltage Drops

When the selected Fan−in−Model or Vfilt capacitor is not adapted to the needs of the application, this can lead to communication issues. The issue occurs when devices are used with an unnecessarily high Fan−in−Model or a too small Vfilt capacitor. Connecting many of these at the end of a long cable can lead to bus voltage drops.

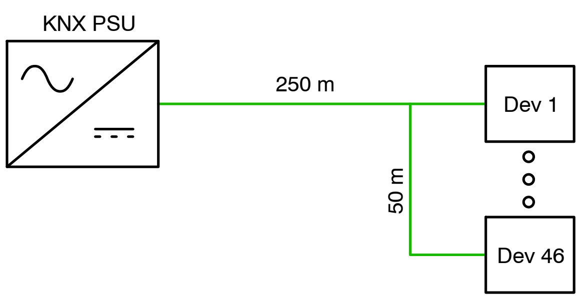

Figure 6. Network Setup Causing Communication Issues

An example of a problematic network setup is given in Figure 6. The KNX power supply is connected at a long distance of 250 m from the rest of the devices. All the devices are at a very short distance of each other with only 50 m of cable length in total between them.

One might think that this is a valid setup, but due to a wrongly selected Fan−in−Model it is not. In this example the application only consumes around 10 mA maximum. But during the design a resistor of 10 kΩ was connected to the FANIN−pin. This can happen when it is accidentally copied from a reference design and is forgotten afterwards. This selects a Fan−in−Model of 40 mA.

Connecting 46 devices at the end of the bus would mean that a power supply with a nominal output current of 1.84 A must be used.

$$\sum_{n=1}^{N} I_{c(n)} = 1.84\ A \qquad \text{(eq. 10)}$$

In this situation a power supply with a nominal output current of only 640 mA is used. This network does not comply with the KNX standard.

When the devices start to communicate with each other, the bus voltage drops to transmit a zero. This causes all other transceivers to stop taking current from the bus. Otherwise this could influence the communication. During the complete transmission of the frame the current must come from the Vfilt capacitor.

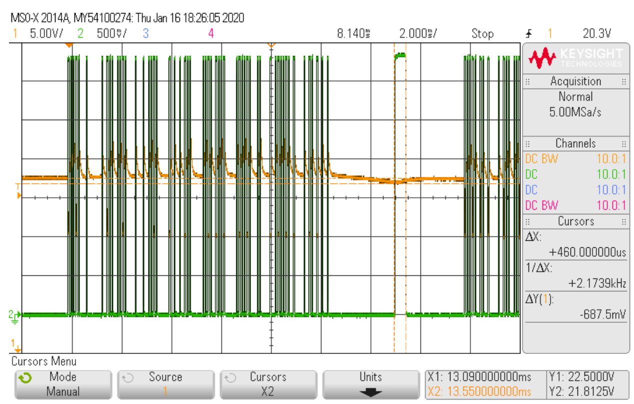

Figure 7. Bus Voltage Drop Caused by Wrong Fan−in−Model Selection (Orange = Bus Voltage, Green = Transceiver Output)

After the frame transmission is finished all these devices will start to pull current from the bus with a slope of 2 mA/ms. This sudden current draw will make the bus voltage drop. Worst case this drop can trigger the transceiver, causing communication to fail. Figure 7 shows an example of a bit transceiver triggering on this voltage drop while it shouldn’t.

This phenomenon has many influencing factors. Not selecting the right Fan−in−Model for your application is contrary to the KNX standard. The standard specifies that the power consumption must be limited to the real needs [3]. The high current slopes can cause the bus voltage to drop.

Connecting the power supply at the other end of a long cable introduces a voltage drop across the cable. When many devices are connected close to each other this can lead to issues. The KNX Basic Course [1] recommends to connect the power supply close to a cluster of more than 30 devices.

Selecting an unnecessary high Fan−in−Model, causes over dimensioning of the power supply. Installers use the Fan−in−Model listed in the datasheet or included in the KNX−database to calculate the nominal output current of the power supply.

A last important factor is the size of the Vfilt capacitor. This capacitor delivers the power during the communication. When selecting a smaller Vfilt capacitor, the voltage across it will be lower at the end of a message. This causes the bus coupler to take more current from the bus to recharge it. When using long cable lengths with clustered devices, this will introduce bus voltage drops disrupting the communication.

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Internet

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

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

APPENDIX A

[4], Table 4, Section 4.4.3

Parameter	Values
DC Input Current (any load)	TP1−64: max. 12 mA for U_{IN} = 20 V to 30 V TP1−256: max. 12 mA for U_{IN} = 20 V to 30 V
Slope of Input Current	max. 0.5 mA/ms
Slope of Input Current for Manually Operated Devices (e.g. push buttons)	max. 2.5 mA/ms

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