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AND8411/D

AMIS-30600 LIN Transceiver Low Power Consumption

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APPLICATION NOTE

Introduction

This document describes how the AMIS−30600 LIN transceiver can be used in low power environments.

Questions

How can I consume less power when the AMIS−30600 is disabled (V_{EN} = 0 V) and what will be the effect on the TxD−, RxD−, INH−, and EN−pin when data is transmitted over the LIN−bus?

Conclusion

Although the AMIS−30600 offers a sleep mode, it is possible that the power consumption is still too high in some applications. To reduce power consumption, V_{CC}, V_{bat} and the LIN pullup resistor can be disconnected without any unwanted effects on the TxD−, RxD−, EN−, and INH−pin[1].

In the Conclusion and Advised Application Schematic Section, an advised application schematic is provided to reduce the AMIS−30600 supply current I_{CC} and total battery current consumption I_{bat} to 0 A (microcontroller ignored and ideal 5 V voltage regulator(s) assumed). In this way the AMIS−30600 power consumption will be very low.

General

The single−wire transceiver AMIS−30600 is a monolithic integrated circuit in a SOIC−8 package. It works as an interface between the protocol controller and the physical bus.

The AMIS−30600 is especially suitable to drive the bus line in LIN systems in automotive and industrial applications. Further it can be used in standard ISO9141 systems.

In order to reduce the current consumption the AMIS−30600 offers a sleep mode. A wakeup caused by a message on the bus pulls the INH−output high until the device is switched to normal operation mode.

For more info about the AMIS−30600 LIN transceiver I refer to the AMIS−30600 datasheet (www.onsemi.com).

Test Setup

To consume less power when the AMIS−30600 is in sleep mode[2], three possible setups will be examined.

In the first setup, V_{BB} will be disconnected or connected to ground[3] (Figure 1: V_{BB} Disconnected or Connected to Ground). The behavior of the TxD−, RxD−, INH−, and EN−pin will be examined when V_{LIN} is between −40 V and +40 V (−40 V < V_{LIN} < +40 V) as also the current in these pins will be measured. Additional, the current consumption of the V_{CC}−pin (AMIS−30600) and the battery current consumption (I_{bat}) will be measured.

This test will be done with the INH−pin connected to an I/O−pin of the microcontroller (by using a 12 V−to−5 V converter) and with the INH−pin pulled to ground (with a 22k resistor).

1. AMIS−30600 is designed for $V_{BB} \geq V_{CC}$ and the measurements are only done on one sample. Because of this, ON Semiconductor cannot be held responsible if results (given in this document or measured yourself) are different than the data sheet parameters or if there is a LIN Physical Spec violation when operating outside the normal supply range (+4.75 V < V_{CC} < +5.25 V and +7.3 V < V_{BB} < +18 V).
2. A wakeup caused by a message on the communication bus automatically puts AMIS−30600 in stand−by mode and switches the INH−pin to high output.
3. Connected to ground without resistor, capacitor or other component.

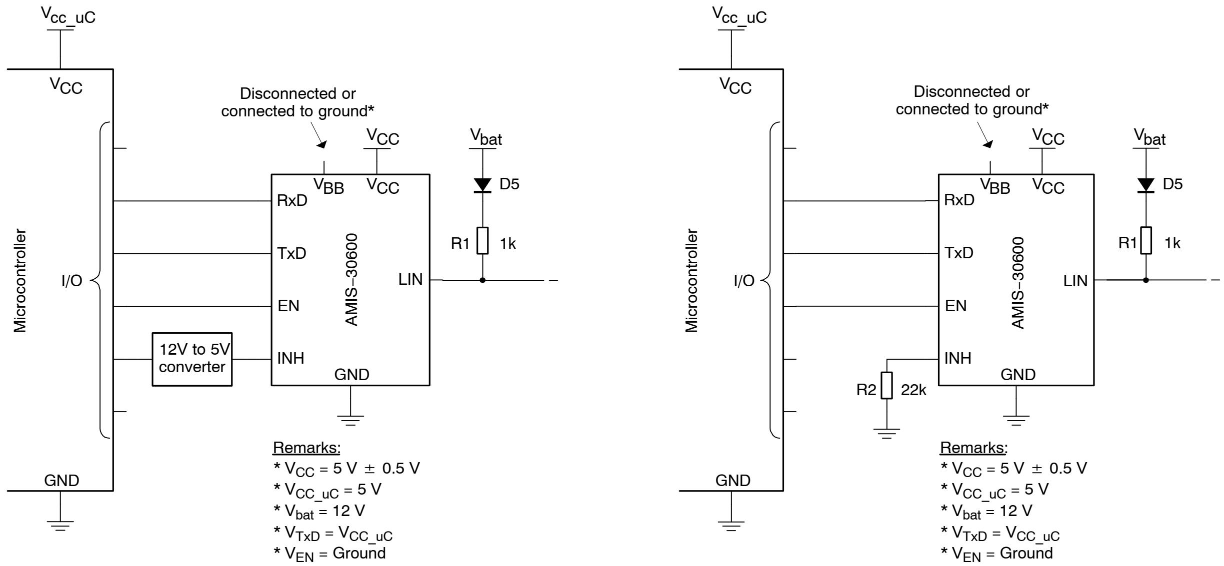

Figure 1. V_{BB} Disconnected or Connected to Ground

In the second test (Figure 2) similar setup will be used but V_{CC} will also be disconnected or connected to ground[4]. Similar behaviors and current consumptions will be examined as the first test.

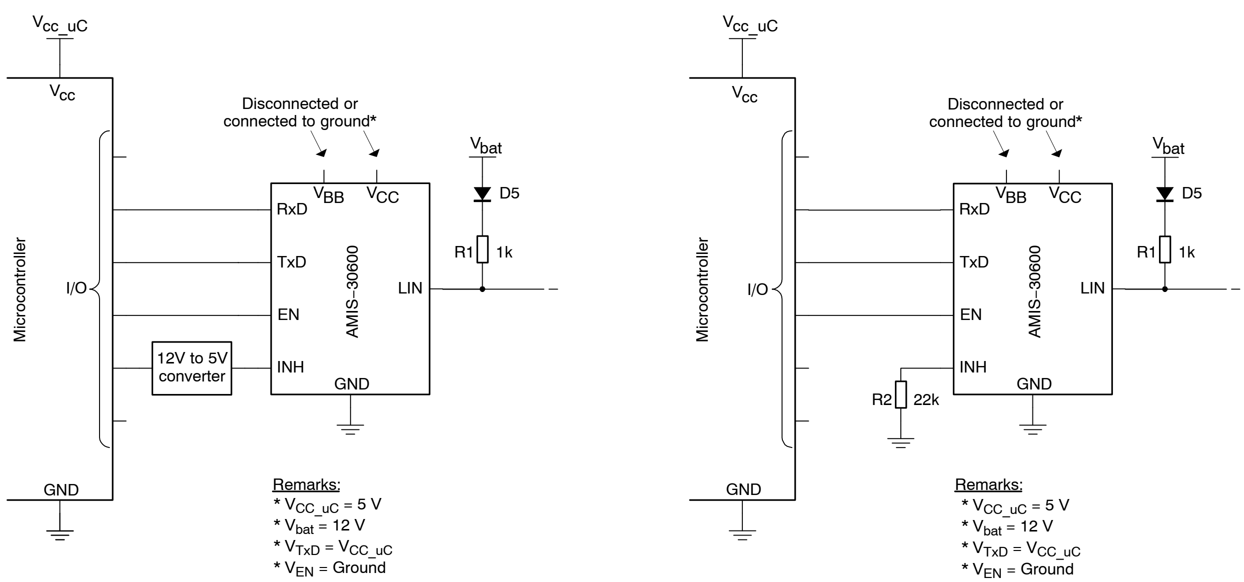

Figure 2. V_{BB} Disconnected or Connected to Ground

4. Connected to ground without resistor, capacitor or other component.

For the last test, the LIN pullup resistor will also be disconnected (see Figure 3).

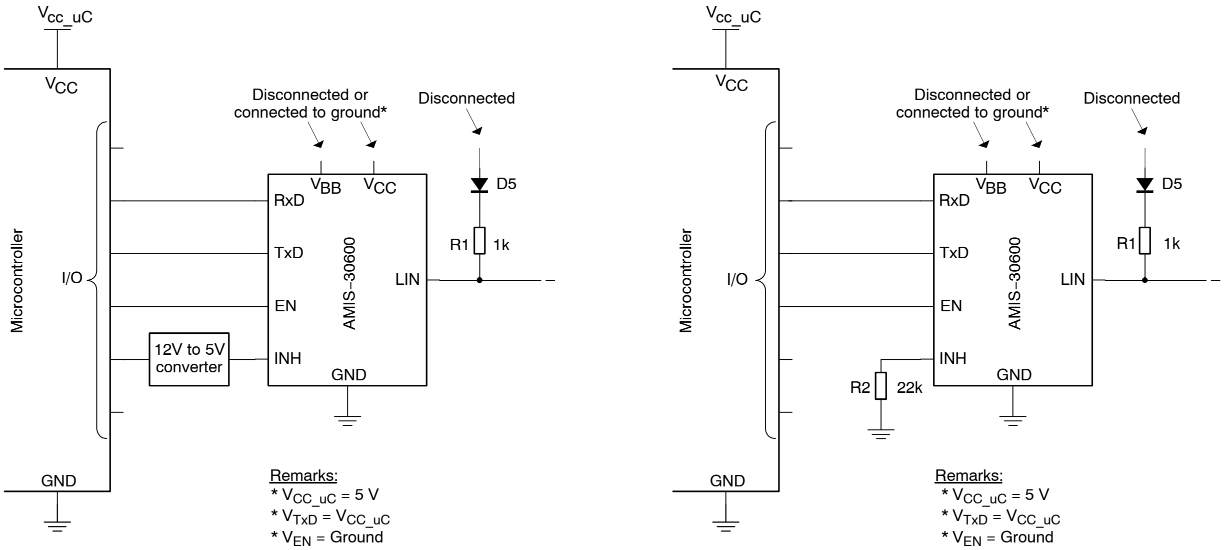

Figure 3. LIN Pullup Resistor Disconnected

Next equipment was used for the measurements:

- **Power Supply**: Thurlby Thandar Instruments PL330QMD and PL310QMD Philips PE1542
- **Curve Tracer**: Tektronix Curve Tracer Type 576
- **μA−Meter**: Keithley 2400 Sourcemeter
- **Oscilloscope**: Tektronik TDS2014, four channel oscilloscope, 100 MHz, 1 GS/s

Remark: For the next tests, the 12 V−to−5 V converter has a high input impedance. In Addendum Section some example schematics of simple 12 V−to−5 V converters are given. They are however not all high impedant.

Technical Information

To examine the effects on the TxD−, RxD−, EN−, and INH−pin a more detailed view of the pins will be given.

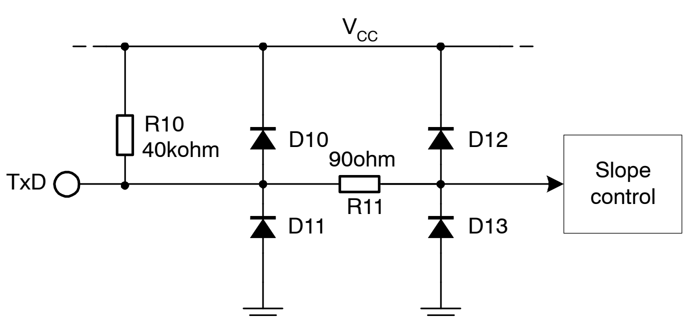

Figure 4. AMIS−30600 TxD−Pin

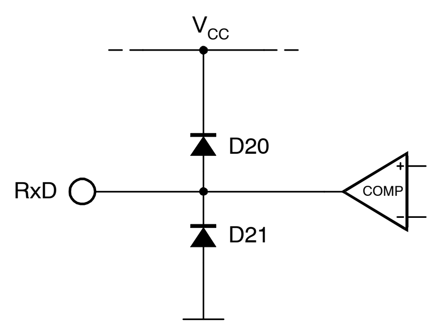

Figure 5. AMIS−30600 RxD−Pin

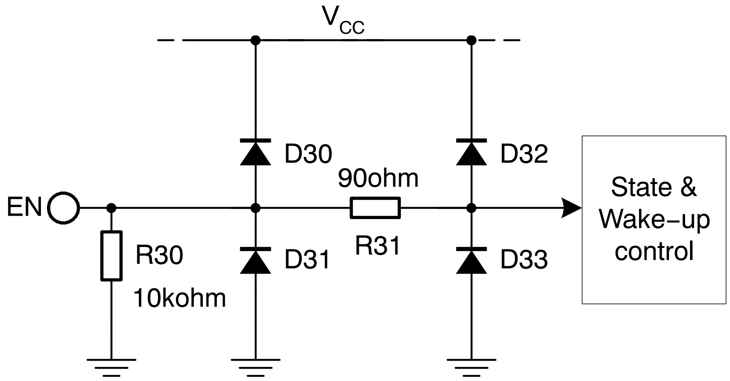

Figure 6. AMIS−30600 EN−Pin

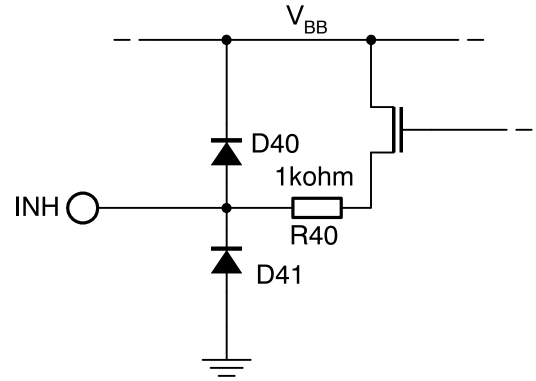

Figure 7. AMIS−30600 INH−Pin

The diodes given in above figures are ESD protection diodes.

Test Results

All tests were done under next test conditions:

- -40 V < V_{LIN} < +40 V
- V_{CC} = 5 V ± 0.5 V
- V_{CC_uC} = 5 V
- V_{bat} = 12 V
- V_{TxD} = high = V_{CC_uC} = 5 V
- V_{EN} = low = 0 V
- T_A = 25°C

All currents measured in next tests are measured when the LIN transceiver is disabled (V_{EN} = 0 V). Also, when V_{BB} or V_{CC} is connected to ground in next measurements, the connection to ground is made without a resistor, capacitor or other component. The effect on the TxD−, RxD−, EN−, and INH−pin is examined and the total current consumption is measured.

It is advised to first read the application note "AMIS−30600: Special Supply Configuration".

V_{BB} Disconnected or Connected to Ground

TxD−pin: V_{BB} disconnected or connected to ground will have no effect on the TxD−pin (-40 V < V_{LIN} < +40 V, INH−pin connected with microcontroller through 12 V−to−5 V converter or connected with ground). The only thing to keep in mind is the difference between the supply voltage of the microcontroller and the AMIS−30600 (if there is no common power supply).

For instance, if the supply voltage of the microcontroller (V_{CC_uC}) is 5 V and the supply voltage of the AMIS−30600 is 4.5 V, the ESD protection diodes D10 and/or D12 could conduct (see Figure 8).

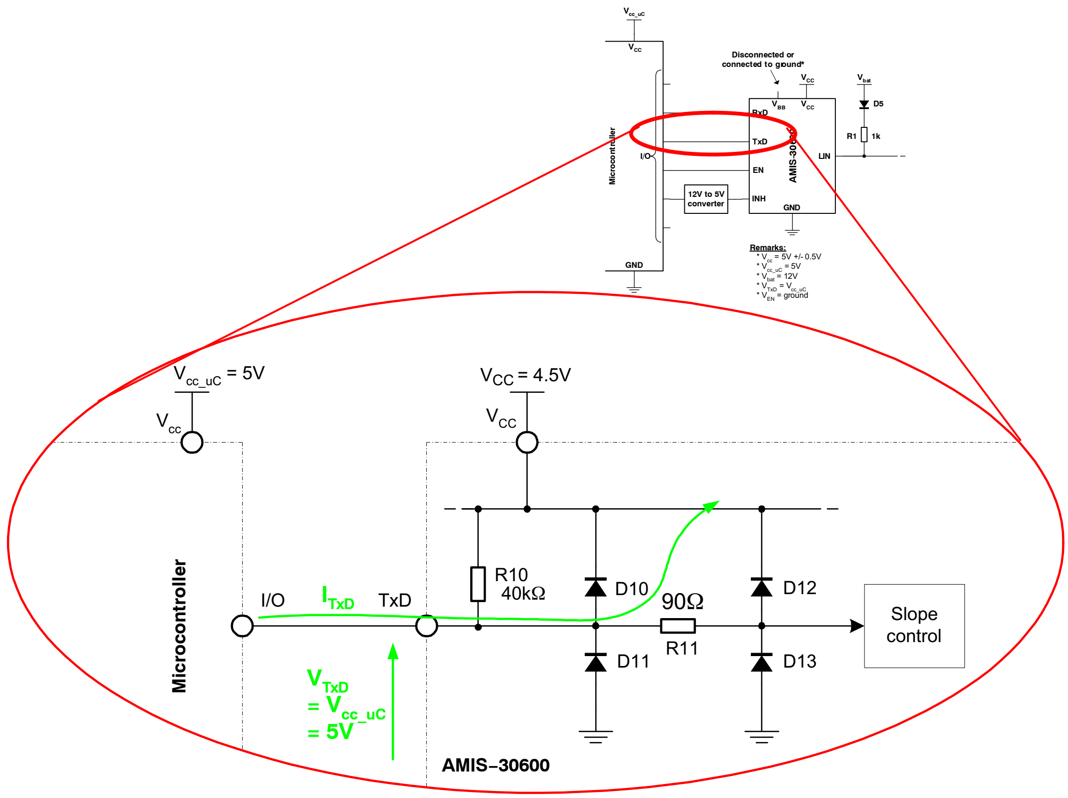

Figure 8. ESD Protection Diode D10 and/or D12 Conducts[5]

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5. Figure displays set up where INH−pin is connected to microcontroller.

During our test, the ESD protection diodes D10 and/or D12 conducted at a forwarded voltage drop of about 550 mV. Because of this, ITxD of the AMIS−30600 is max $\pm 12.5\ \mu A$[6] ($[V_{CC\_uC} - V_{CC}] / R10$ with $V_{CC} = 5\ V \pm 0.5\ V$) (see Figure 9).

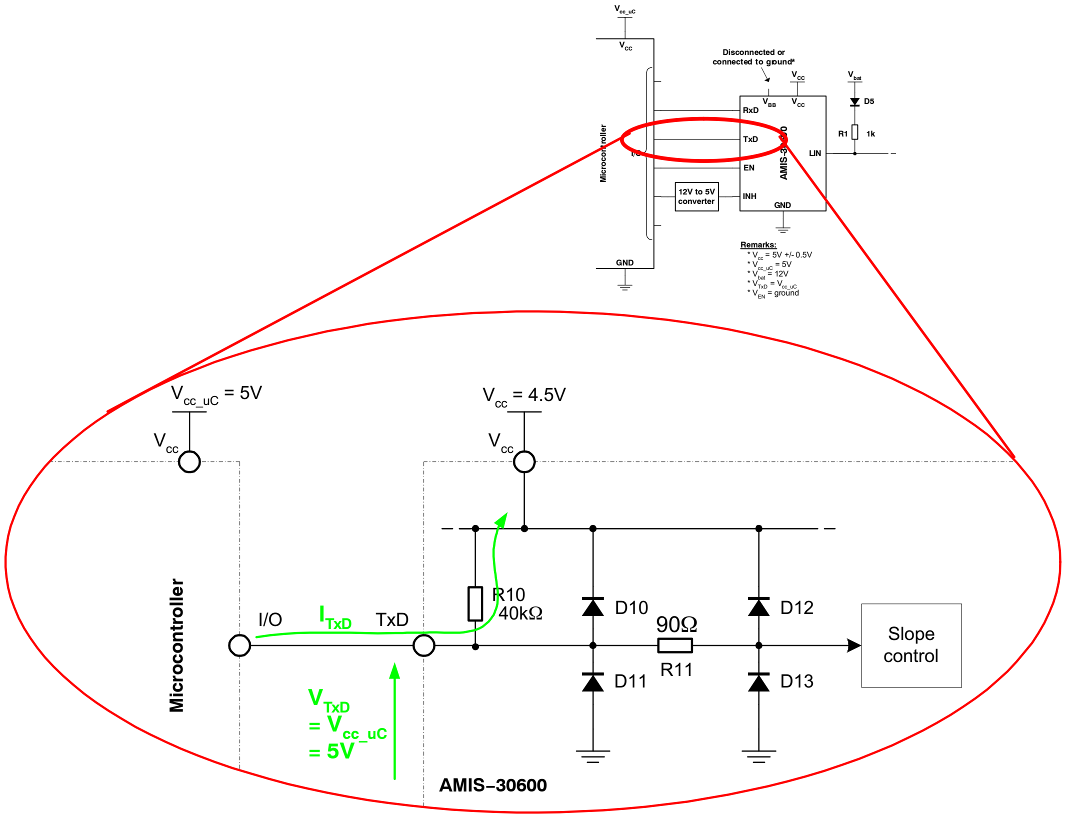

Figure 9. I_{TXD} when ESD Protection Diodes Don’t Conduct[7]

6. Positive current means current is injected in TxD−pin of AMIS−30600.
7. Figure displays set up where INH−pin is connected with microcontroller.

RxD−pin: If EN−pin is pulled low, V_{RxD} will be high (= V_{CC} of AMIS−30600). A voltage on the LIN−pin will have no influence on the RxD−pin (V_{BB} disconnected or connected to ground, INH−pin connected to 12 V−to−5 V converter or pulled to ground).

Again, the only thing to keep in mind is the difference between power supplies. One would assume that this would not be a problem. The microcontroller I/O's however have in most cases ESD protection diodes. If for instance V_{CC_uC} is 5 V and V_{CC} of AMIS−30600 is 5.5 V, ESD protection diode D1 could conduct (depends on ESD protection diode). See Figure 10: ESD Protection Diode D1 Conducts.

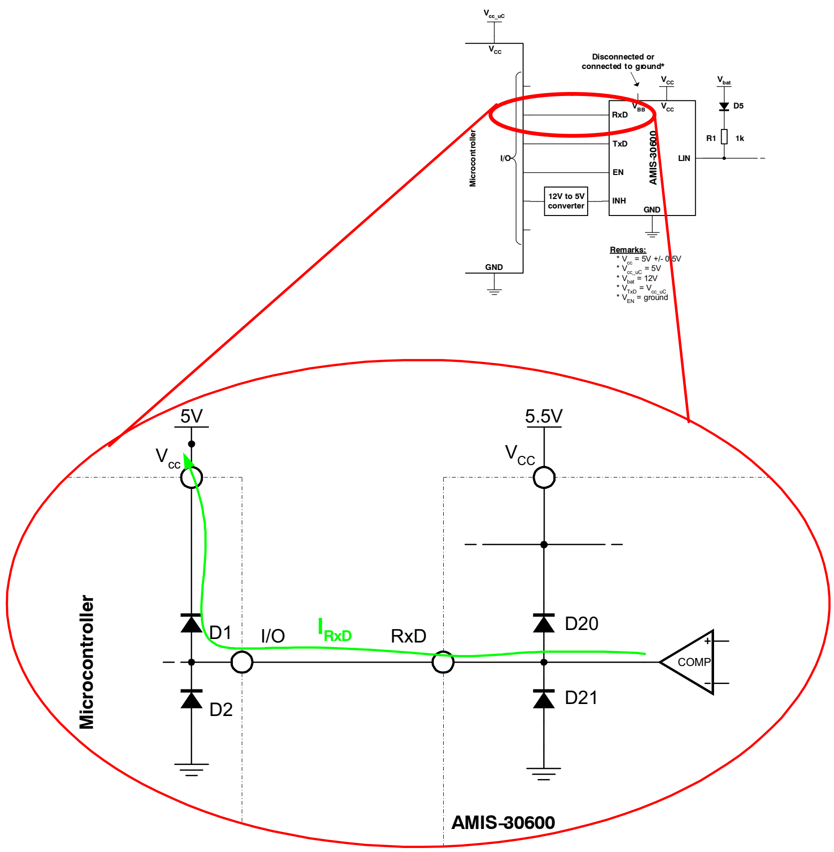

Figure 10. ESD Protection Diode D1 Conducts[8]

During our measurements, the current I_{RxD} was 36 μA[9].

EN−pin: The EN−pin is pulled low by the microcontroller. A voltage on the LIN−bus will have no effect on this pin when V_{BB} is disconnected or connected to ground and INH−pin connected to 12 V−to−5 V converter or to ground.

INH−pin: A voltage on the LIN−pin when V_{BB} is connected to ground will have no influence on the INH−pin when INH−pin is connected to microcontroller (via 12 V−to−5 V converter) or to ground by 22k (V_{INH} = 0 V).

If V_{BB} is disconnected, V_{BB} will be powered through V_{CC}. The voltage on the INH−pin will be maximum +3.5 V (V_{LIN} = +40 V) and minimum –500 mV (V_{LIN} = –40 V) if V_{CC} is 5.5 V and INH−pin connected with 12 V−to−5 V converter. If INH−pin is connected with ground through a 22k resistor, V_{INH} is maximum 500 mV and minimum −500 mV when V_{CC} = 5.5 V. The maximum current measured at the INH−pin is ±20 μA.

8. Figure displays set up where INH−pin is connected to microcontroller.
9. Negative current means current is injected.

Table 1 shows the maximum current consumption for the different setups (see Figure 1: V_{BB} Disconnected or Connected to Ground).

Table 1. MAXIMUM POWER CONSUMPTION WHEN V_{BB} IS 12 V, DISCONNECTED OR CONNECTED TO GROUND

	V_{BB} = 12 V			V_{BB} Disconnected		V_{BB} Connected to Ground	
	I_{CC} (μA) (Note 1)	I_{bat} (mA)	I_{BB} (mA)	I_{CC} (μA)	I_{bat} (mA)	I_{CC} (μA)	I_{bat} (mA)
INH−pin connected with microcontroller	−12 (V_{CC} = 4.5 V) 100 (V_{CC} = 5.5 V)	52	1.7	350 (V_{CC} = 4.5 V) 470 (V_{CC} = 5.5 V)	52 (Note 2)	420	52
INH−pin connected with ground	−12 (V_{CC} = 4.5 V) 100 (V_{CC} = 5.5 V)	52	2.2	350 (V_{CC} = 4.5 V) 470 (V_{CC} = 5.5 V)	52	400	52 (Note 2)

1. Positive current means injected current in V_{CC}−pin.
2. V_{LIN} = −40 V.

For the current consumption only the current consumed by the AMIS−30600 (I_{CC} and I_{BB} if relevant) and the battery consumption (I_{bat}) was measured (see Figure 11).

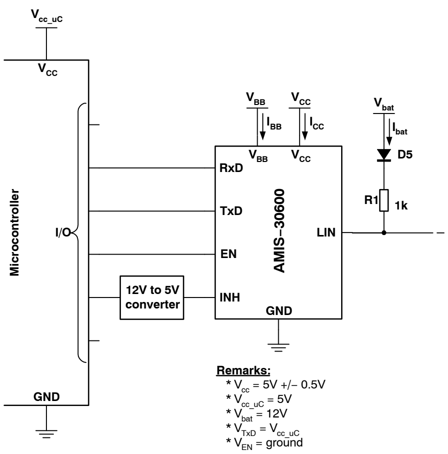

Figure 11. Current Consumption First Setup

In Table 1, one can see that the current consumption of the AMIS−30600 (I_{CC}) is between –12 μA and 100 μA for V_{BB} = 12 V. The reason I_{CC} is negative when V_{CC} is 4.5 V is because V_{CC_uC} is 5 V. When V_{CC} would be 5 V, the current I_{cc} would be less than 1 μA (see also datasheet).

For V_{BB} disconnected or connected to ground, I_{CC} is significant higher. This is because there is a connection between V_{CC} and V_{BB} of the AMIS−30600 and V_{CC} will try to power V_{BB}.

The maximum current I_{bat} measured is in all cases 52 mA (V_{LIN} = −40 V). This can also be calculated as the voltage drop over R1 (1 kΩ) divided by 1k. See also Figure 11.

If a decoupling capacitor would still be present on the V_{BB}−pin when V_{BB} is disconnected (see Figure 12), the current consumption would be the same as V_{BB} disconnected (see Table 1).

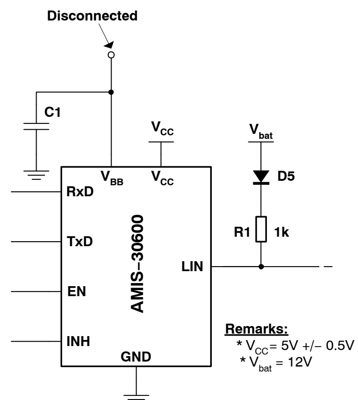

Figure 12. Decoupling Capacitor Present when V_{BB} is Disconnected

<u>Intermediate Conclusion</u>:

One could disconnect V_{BB} to reduce battery current consumption. The disadvantage is that I_{CC} will increase. Independent from this care has to be taken in voltage supply. Best way is to take one voltage supply for microcontroller and LIN transceiver (see Figure 13). If two separate voltage supplies are used, make sure the tolerance is not too large[10].

It's advised to connect the TxD−pin of the LIN transceiver to an open−collector or open−drain output of the microcontroller when using two separate power supplies. In this way the ESD protection diodes D10 and/or D12 (see Figure 8) will not conduct if the difference between power supplies is too large.

10. Voltage supply tolerance may also be not too large when LIN transceiver is operating in normal mode.

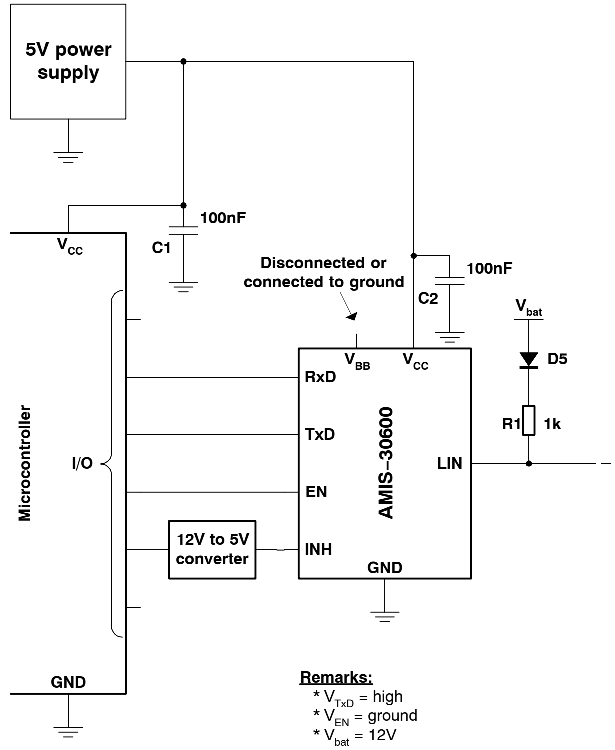

Figure 13. Use One Power Supply to Supply µC and AMIS−30600

V_{CC} Disconnected or Connected to Ground (see Figure 2)

TxD−Pin: When V_{CC} is disconnected (V_{BB} disconnected or connected to ground), the TxD−pin will power V_{CC} of the AMIS−30600 (see Figure 14). Keep in mind that there is a connection between V_{CC} and V_{BB} of the AMIS−30600 which will all together result in a “large” I_{TxD} of maximum 450 µA (V_{LIN} = −40 V and V_{BB} disconnected or connected to ground).

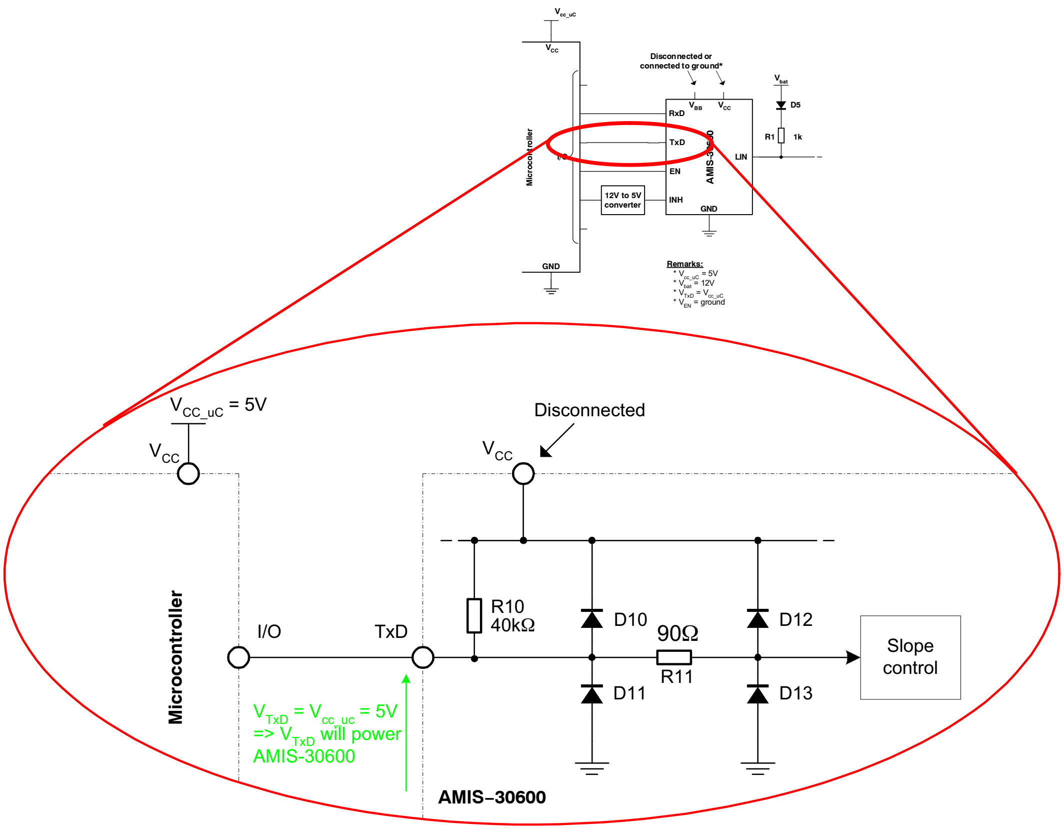

Figure 14. V_{TxD} will Power AMIS−30600 when V_{CC} is Disconnected[11]

Connecting V_{CC} to ground may not be done. This will result in a large current because of the ESD protection diodes D10 and D12 (see Figure 14).

There is no influence on the TxD−pin when a voltage is applied to the LIN−pin (V_{CC} connected to ground not measured).

RxD−pin: Because the voltage on the TxD−pin will power the AMIS−30600, V_{RxD} will be about 5 V (V_{CC_uC}) when V_{CC} is disconnected. When V_{BB} is disconnected or connected to ground (V_{CC} disconnected), a voltage on the LIN−pin will have no influence on the RxD−pin. The current I_{RxD} is less than 1 μA. Because of above reason (see TxD−pin), V_{CC} may not be connected to ground.

EN−pin: EN−pin is pulled to ground. No influence on this pin noticed when V_{BB} is disconnected or connected to ground and V_{CC} is disconnected ($-40\ V < V_{LIN} < +40\ V$). Similar, V_{CC} may not be connected to ground (see TxD−pin).

INH−pin: The maximum voltage on the INH−pin when V_{CC} and V_{BB} are disconnected is +3.5 V (V_{LIN} = +40 V and INH−pin connected to 12 V−to−5 V converter). The minimum voltage is −500 mV (V_{LIN} = −40 V, INH−pin connected to 12 V−to−5 V converter or connected to ground). The maximum current measured at this pin is ±20 μA[12].

11. Figure displays set up where INH−pin is connected to microcontroller.
12. Negative current means current is injected.

When V_{CC} is disconnected and V_{BB} connected to ground, the voltage on the INH−pin is 0 V (INH−pin connected to 12 V−to−5 V converter or connected to ground).

Similar as above (TxD−pin), V_{CC} may not be connected to ground.

Also here no influence on the INH−pin (V_{cc} connected to ground not measured) when a voltage on the LIN−bus is applied.

Table 2 shows the maximum battery current consumption I_{bat} for the different setups.

Table 2. MAXIMUM POWER CONSUMPTION WHEN V_{CC} IS DISCONNECTED OR CONNECTED TO GROUND

	I_{bat} [mA]			
	V_{BB} Disconnected		V_{BB} to Ground	
	V_{CC} Disconnected	V_{CC} to Ground	V_{CC} Disconnected	V_{CC} to Ground
INH−pin connected with microcontroller	52 (Note 3)	NA	52 (Note 3)	NA
INH−pin connected with ground	52	NA	52	NA

3. V_{LIN} = −40 V.

In Table 2 one can see that the battery current is similar as when V_{CC} is connected. The only advantage is that I_{CC} is 0 A. But because V_{TxD} is 5 V (pulled high by the microcontroller), the microcontroller has to deliver the supply current for the AMIS−30600.

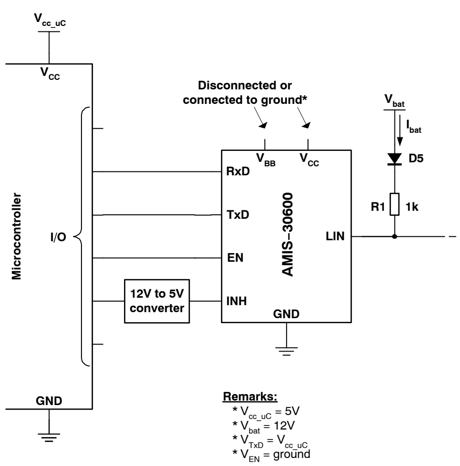

Figure 15. Current Consumption Second Setup

If there is still, when V_{CC} is disconnected, a decoupling capacitor connected with the V_{CC}−pin of the AMIS−30600, the results are similar as V_{CC} disconnected (see Table 2). Similar for the V_{BB}−pin of the AMIS−30600. See also Figure 16.

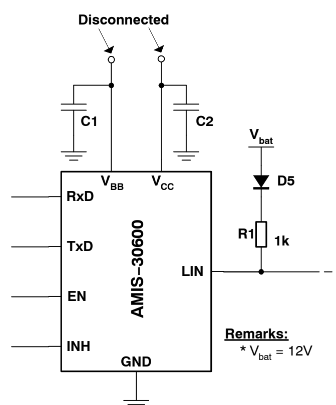

Figure 16. Decoupling Capacitor Present when V_{BB} and V_{CC} Disconnected

Intermediate Conclusion:

Disconnecting or connecting V_{BB} to ground and disconnecting V_{CC} may be done. The supply current for the AMIS−30600 I_{CC} will be 0 A. Because V_{TxD} is pulled high by the microcontroller however, the TxD−pin will power the AMIS−30600 (V_{CC} disconnected). The microcontroller needs to deliver the supply current for the AMIS−30600. The result is that the total power consumption did not reduce compared to previous setup.

Connecting V_{CC} to ground will result in a high current because of the ESD protection diodes.

It’s advised to connect the TxD−pin of the AMIS−30600 to an open−collector or open−drain output of the microcontroller. In this way the microcontroller will not power the LIN transceiver through the TxD−pin resulting in less (about 500 μA) total power consumption.

One can see that the battery current I_{bat} is still high (max 52 mA). To reduce this, one can try to disconnect the LIN pullup resistor (see the V_{CC} Disconnected or Connected to Ground Section).

LIN Pullup Resistor Disconnected (see Figure 3)

TxD−pin: Similar as without LIN pullup resistor disconnected (see the V_{CC} Disconnected or Connected to Ground Section) with the exception that the battery current consumption I_{bat} is 0 A.

RxD−pin: Similar as without LIN pullup resistor disconnected (see the V_{CC} Disconnected or Connected to Ground Section) except that I_{bat} is 0 A.

EN−pin: Similar as LIN pullup resistor connected (see the V_{CC} Disconnected or Connected to Ground Section) except that I_{bat} is 0 A.

INH−pin: Similar as without LIN pullup resistor disconnected (see the V_{CC} Disconnected or Connected to Ground Section) except that I_{bat} is 0 A.

There is no influence on the LIN−network when the LIN pull−up resistor is disconnected. Keep in mind that, when the LIN pullup resistor is disconnected and V_{BB} of the AMIS−30600 is connected to ground or disconnected, another node should pull the LIN bus to 12 V.

Intermediate Conclusion:

One can disconnect the LIN pullup resistor to reduce battery consumption. The consumed battery current is in all cases 0 A which is significant lower than previous test (see the V_{CC} Disconnected or Connected to Ground Section).

Conclusion and Advised Application Schematic

To reduce the power consumption of the AMIS−30600 when disabled (V_{EN} = 0 V), one can disconnect V_{BB} or connect it to ground and disconnect V_{CC}. It's, however, advised to connect the TxD−pin of the AMIS−30600 with an open−collector or open−drain output of the microcontroller otherwise the microcontroller will try to power the LIN transceiver when V_{CC} is disconnected.

To reduce battery consumption, the LIN pullup resistor can be disconnected.

Next schematic gives a better view on an advised application schematic.

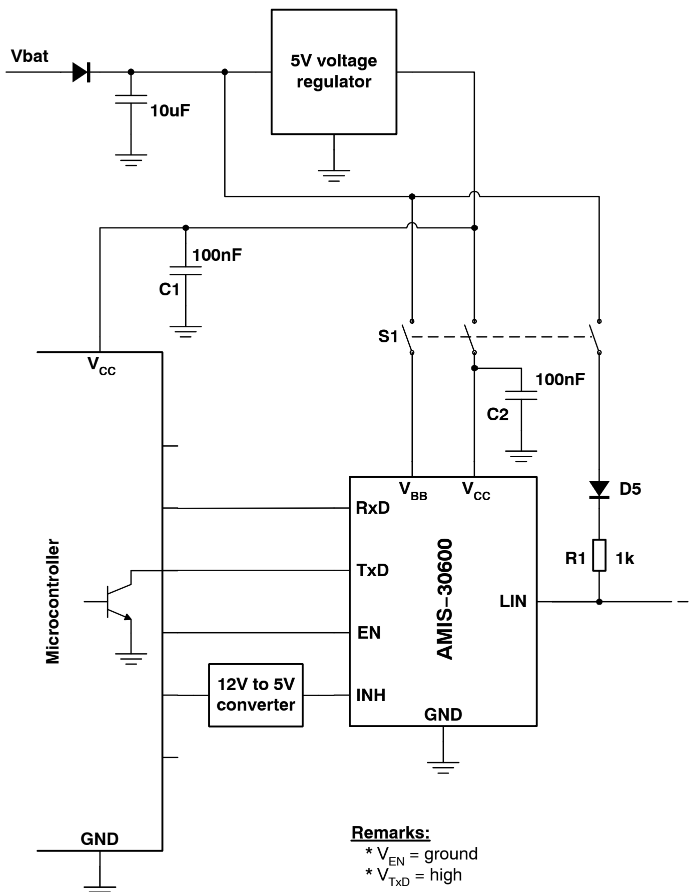

Figure 17. Advised Application Schematic

In Figure 17 one can see that an open−collector is used to control the TxD−pin of the AMIS−30600. One can also see that one power supply is used to power the microcontroller and AMIS−30600. In this way the voltage tolerance may be high[13].

13. 5 V voltage regulator has to stay within the operating range of the AMIS−30600 and the microcontroller.

Be aware that it is possible that an additional ESD protection diode should be added to the open−collector or open−drain output of the microcontroller (see data sheet microcontroller).

When V_{CC} of the LIN transceiver is disconnected, the decoupling capacitor C2 will still be connected to the V_{CC}−pin of the LIN transceiver. This is no issue.

With above schematic, the battery consumption I_{bat} is 0 A[14] (−40 V < V_{LIN} < +40 V). Keep in mind that another node should pull the LIN−bus to 12 V.

Applying a voltage on the LIN bus (−40 V < V_{LIN} < +40 V) will have no influence on the TxD−, RxD−, EN− and INH−pin. The current for these pins was always lower than 2 μA except for the INH−pin when the INH−pin is pulled to ground with a 22k resistor. The current in the INH−pin will then be maximum 20 μA (because of a low voltage drop over the 22k resistor when V_{LIN} is negative).

In Figure 17, one can see that all the three switches will close at once (S1). When S1 is closed, the LIN transceiver is full powered.

In Figure 17 a triple terminal switch is used (S1). One can reduce this by connecting the INH−pin with the 5 V voltage regulator (where it's initially designed for). When the LIN transceiver goes to sleep mode (V_{EN} = 0 V), INH−pin will switch of the 5 V voltage regulator. Then the microcontroller can disconnect V_{BB} and the LIN pullup resistor (S1). As long as V_{BB} is disconnected, the LIN transceiver will be in an off−state and will not disturb the network[15]. From the moment the V_{BB}−pin of the AMIS−30600 is reconnected by the microcontroller, INH−pin will become high (LIN transceiver in standby mode) and the 5 V voltage regulator will switch back on. The microcontroller can switch the LIN transceiver in normal mode by pulling the EN−pin high.

Figure 18 gives a better view on this.

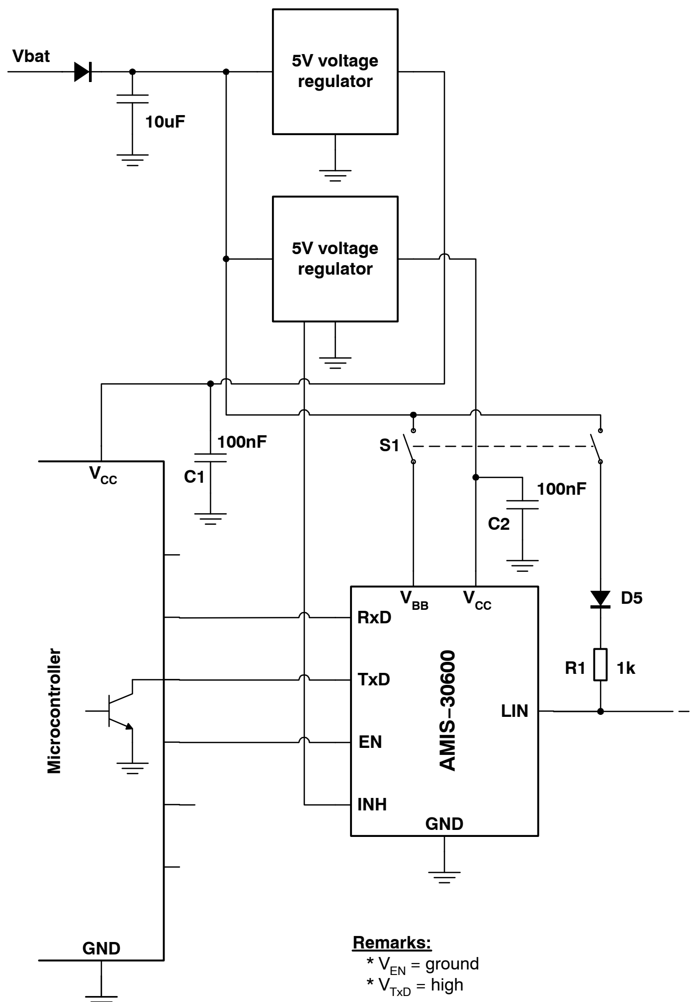

Figure 18. INH−pin Connected with 5 V Voltage Regulator

14. Power consumption microcontroller ignored and ideal 5 V voltage regulator assumed.
15. Keep in mind that when V_{BB} is disconnected, INH−pin cannot be used to detect a wakeup on the LIN bus (for this V_{BB} should be connected).

In Figure 18, one can see that two 5 V voltage regulators are used. If only one voltage regulator would be used and the voltage regulator is switched off to reduce power consumption, the microcontroller is also switch off. The microcontroller will most probably control the switch S1 which can not be done anymore if the microcontroller is not powered. To solve this two 5 V voltage regulators are used and only the one supplying the LIN transceiver is switched off.

It will be no issue using two separate power supplies when care is taken in choosing the two 5 V voltage regulators.

One could also use the INH−pin to disconnect the LIN pullup resistor (see Figure 19). When the AMIS−30600 is put in sleep mode, the LIN pull−up resistor is disconnected and the supply voltage V_{CC} is switch off (INH−pin high impedant). The microcontroller can now switch off V_{BB} (S1 open).

From the moment the LIN transceiver has to be switched back on, S1 should be closed by the microcontroller. The LIN transceiver will come in standby mode (INH−pin is high). Because of this, the 5 V voltage regulator will be switched on and the pullup resistor will be reconnected. The microcontroller can put the AMIS−30600 in normal mode by switching the EN−pin high.

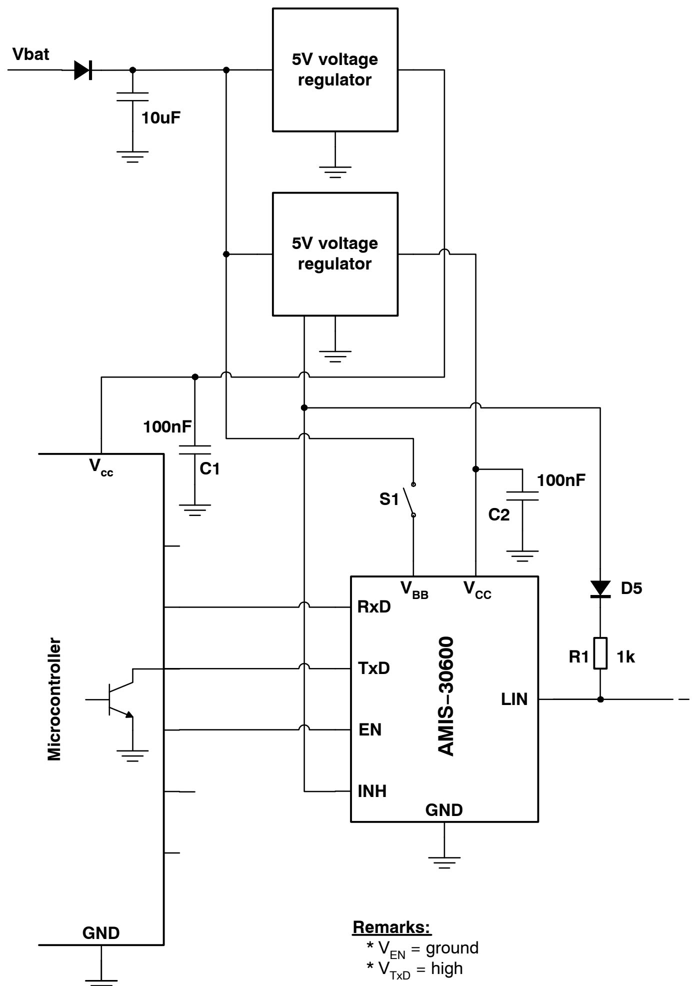

Figure 19. INH−Pin used to Disconnect LIN Pullup Resistor

There was no disturbance measured on the LIN−network when using above circuit (−40 V < V_{LIN} < +40 V).

One can see in Figures 18 and 19 that the 12 V−to−5 V converter is not used anymore. This is because when the microcontroller pulls the EN−pin low, the microcontroller automatically knows that INH−pin will become floating and that the V_{BB}−pin and the LIN pullup resistor will be disconnected.

ADDENDUM

The following figures display simple 12 V−to−5 V converters.

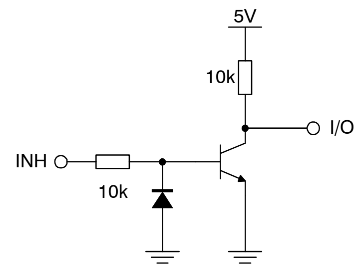

Figure 20. Simple 12 V−to−5 V Converter with Transistor

Figure 20 is similar to the circuit used for a RS232 level converter. The Disadvantage of this is that it's an inverter.

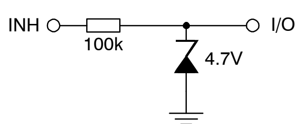

Figure 21. Simple 12 V−to−5 V Converter with Zener Diode

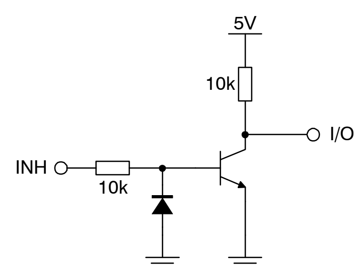

Figure 22. Simple 12 V−to−5 V Converter with Comparator

In Figure 22, a comparator with open−collector is used. The trigger level is about 10 V.

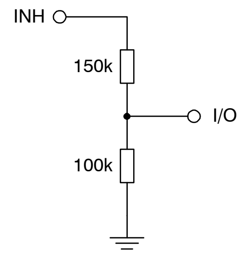

Figure 23. Simple 12 V−to−5 V Converter with Resistors

In Figure 23, one has to be careful in choosing the resistors. The voltage on the I/O−pin may be maximum 5 V. Assumed is that the I/O−pin of the microcontroller is high impedant.

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