AMIS-30600 LIN Transceiver

Low Power Consumption

Application Note 30600-01

1.0 Introduction

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

1.1 Questions

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

1.2 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 pull-up resistor can be disconnected without any unwanted effects on the TxD-, RxD-, EN-, and INH-pin[1].

In Section 6.0, an advised application schematic is provided to reduce the AMIS-30600 supply current I_{cc} and total battery current consumption I_{bat} to 0A (microcontroller ignored and ideal 5V voltage regulator(s) assumed). In this way the AMIS-30600 power consumption will be very low.

2.0 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 wake-up 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 data sheet (www.amis.com).

3.0 Test Set-up

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

In the first set up, V_{bb} will be disconnected or connected to ground[3] (Figure 1: Vbb Disconnected or Connected to Ground). The behavior of the
TxD-, RxD-, INH-, and EN-pin will be examined when V_{LIN} is between -40V and +40V (-40V<V_{LIN}< +40V) 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.

[1] AMIS-30600 is designed for V_{bb} > = V_{cc} and the measurements are only done on one sample. Because of this, AMIS 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 (+4.75V < V_{cc} < +5.25V and +7.3V < V_{bb} < +18V).
[2] A wake-up 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.

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

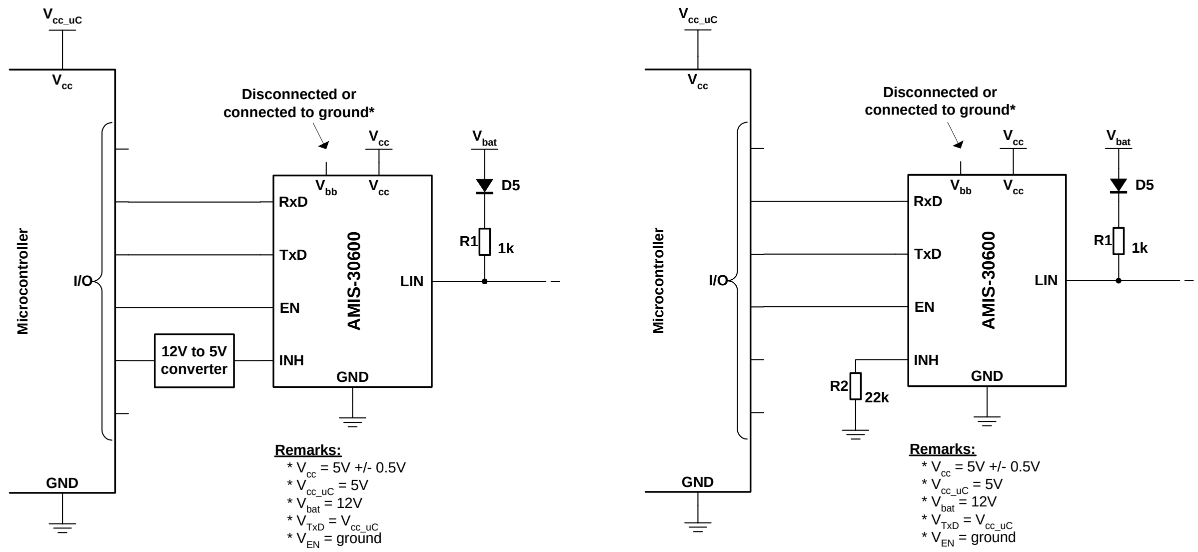

Figure 1: V_{bb} Disconnected or Connected to Ground

In the second test (Figure 2) similar set up will be used but V_{cc} will also be disconnected or connected to ground[3]. Similar behaviors and current consumptions will be examined as the first test.

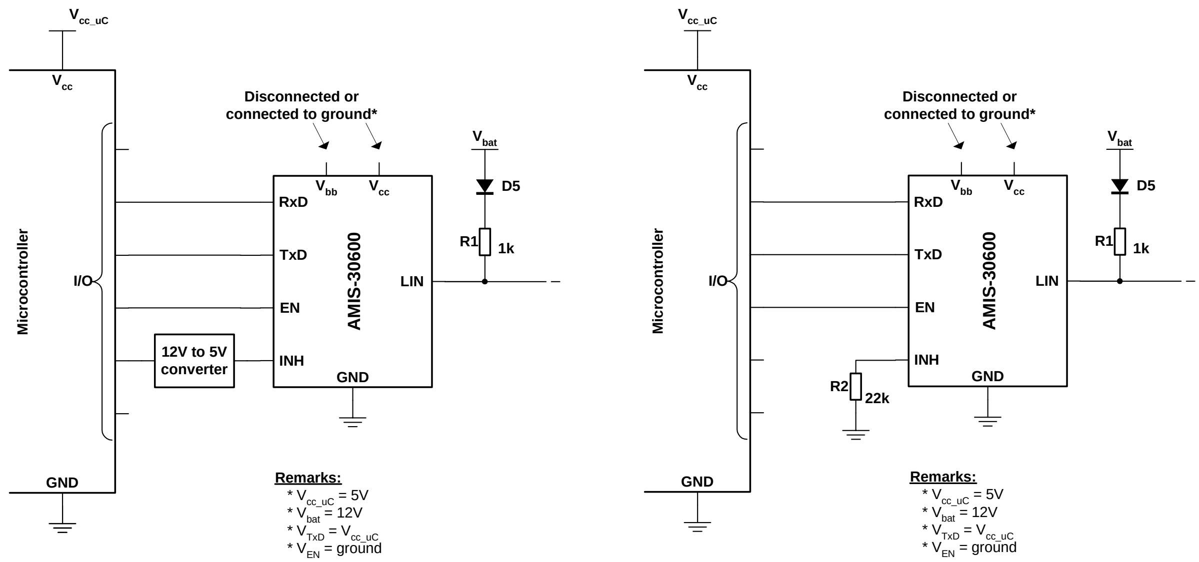

Figure 2: V_{cc} Disconnected or Connected to Ground

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

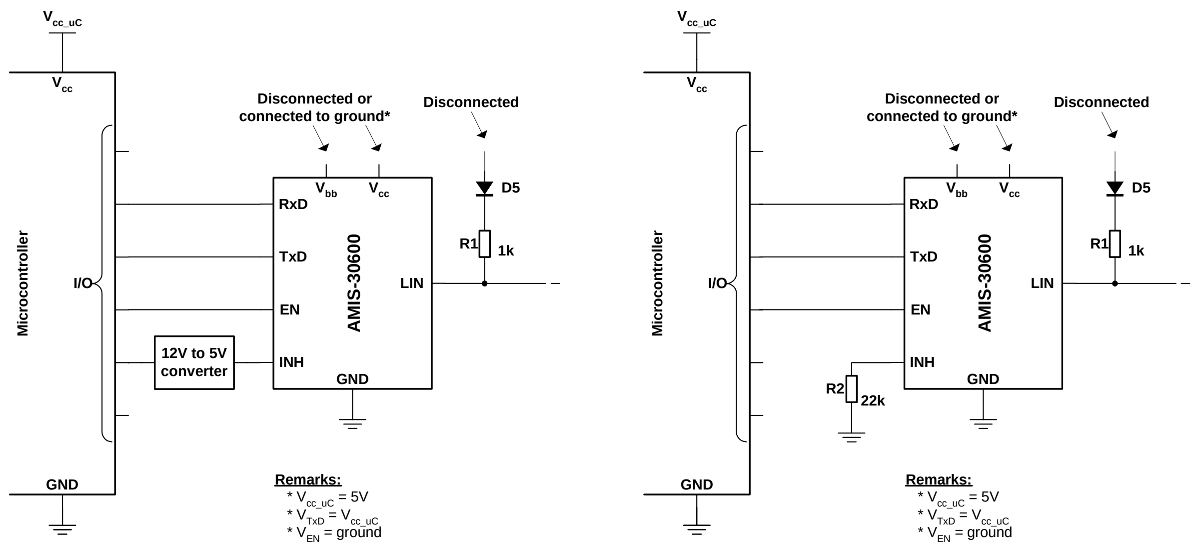

Figure 3: LIN Pull-up Resistor Disconnected

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, 100MHz, 1GS/s

Remark:
For the next tests, the 12V-to-5V converter has a high input impedance. In Section 7.0 Addendum some example schematics of simple 12V-to-5V converters are given. They are however not all high impedant.

4.0 Technical Information

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

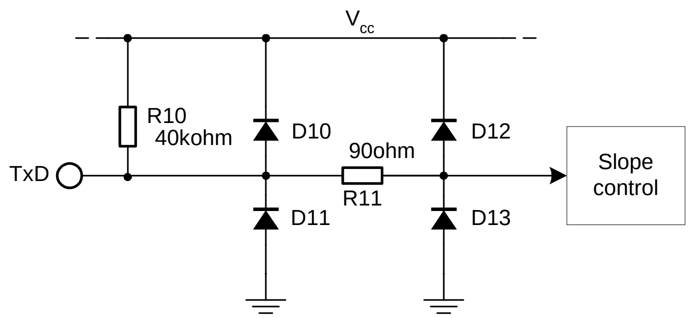

Figure 4: AMIS-30600 TxD-pin

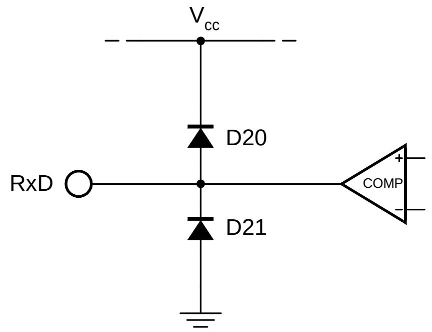

Figure 5: AMIS-30600 RxD-pin

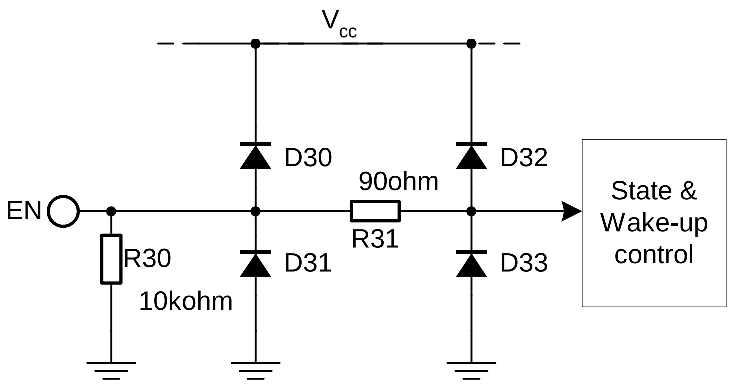

Figure 6: AMIS-30600 EN-pin

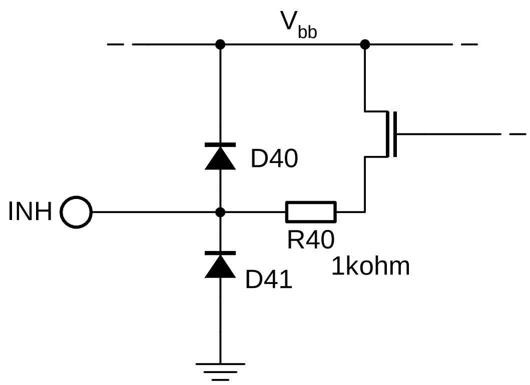

Figure 7: AMIS-30600 INH-pin

The diodes given in above figures are ESD protection diodes.

5.0 Test Results

All tests were done under next test conditions:

- $-40V < V_{LIN} < +40V$
- $V_{cc} = 5V$ +/-0.5V
- $V_{cc\_uc} = 5V$
- $V_{bat} = 12V$
- V_{TxD} = high = $V_{cc\_uC} = 5V$
- V_{EN} = low = 0V
- $T_{amb} = 25°C$

All currents measured in next tests are measured when the LIN transceiver is disabled (V_{EN}=0V). 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".

5.1 V_{bb} Disconnected or Connected to Ground

TxD-pin: V_{bb} disconnected or connected to ground will have no effect on the TxD-pin ($-40V < V_{LIN} < +40V$, INH-pin connected with microcontroller through 12V-to-5V 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 5V and the supply voltage of the AMIS-30600 is 4.5V, the ESD protection diodes D10 and/or D12 could conduct (see Figure 8).

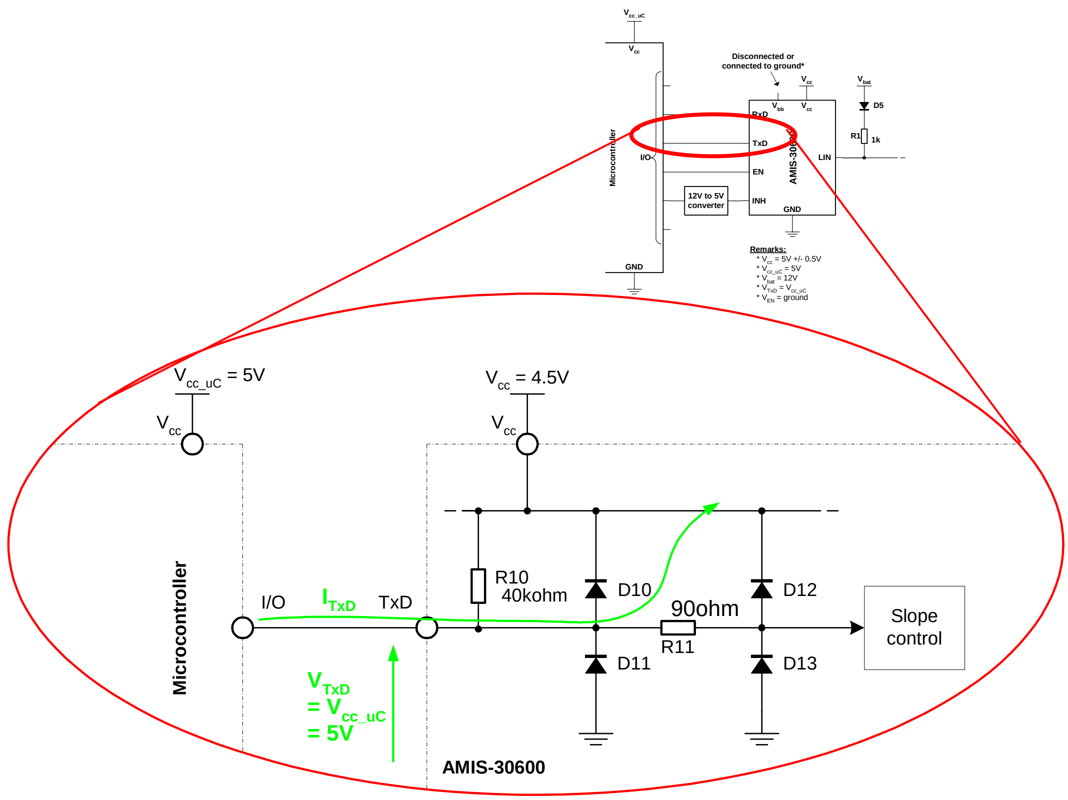

Figure 8: ESD Protection Diode D10 and/or D12 Conducts[4]

[4] 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 550mV. Because of this, I_{TxD} of the AMIS-30600 is max +/-12,5µA[5] ([V_{cc_uC} – V_{cc}] / R10 with V_{cc} = 5V ±0.5V) (see Figure 9).

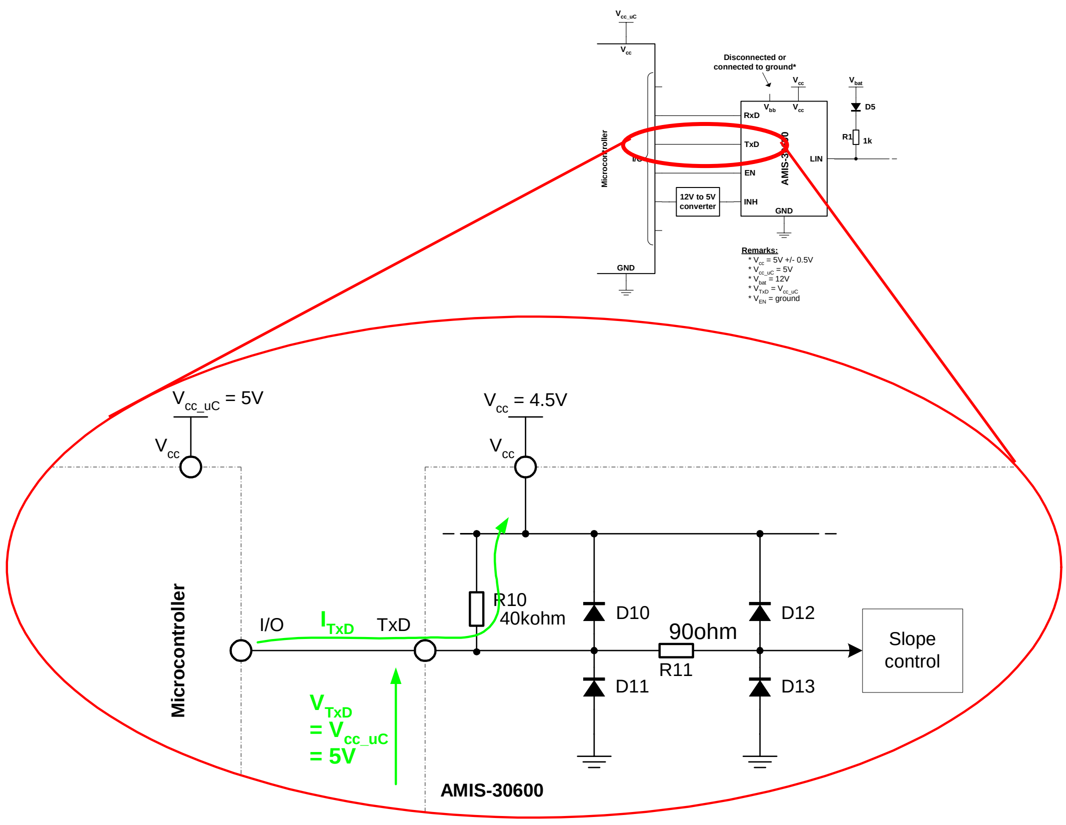

Figure 9: I_{TXD} when ESD Protection Diodes don't Conduct[6]

[5] Positive current means current is injected in TxD-pin of AMIS-30600.
[6] 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 12V-to-5V 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 5V and V_{cc} of AMIS-30600 is 5.5V, ESD protection diode D1 could conduct (depends on ESD protection diode). See Figure 10: ESD Protection Diode D1 Conducts.

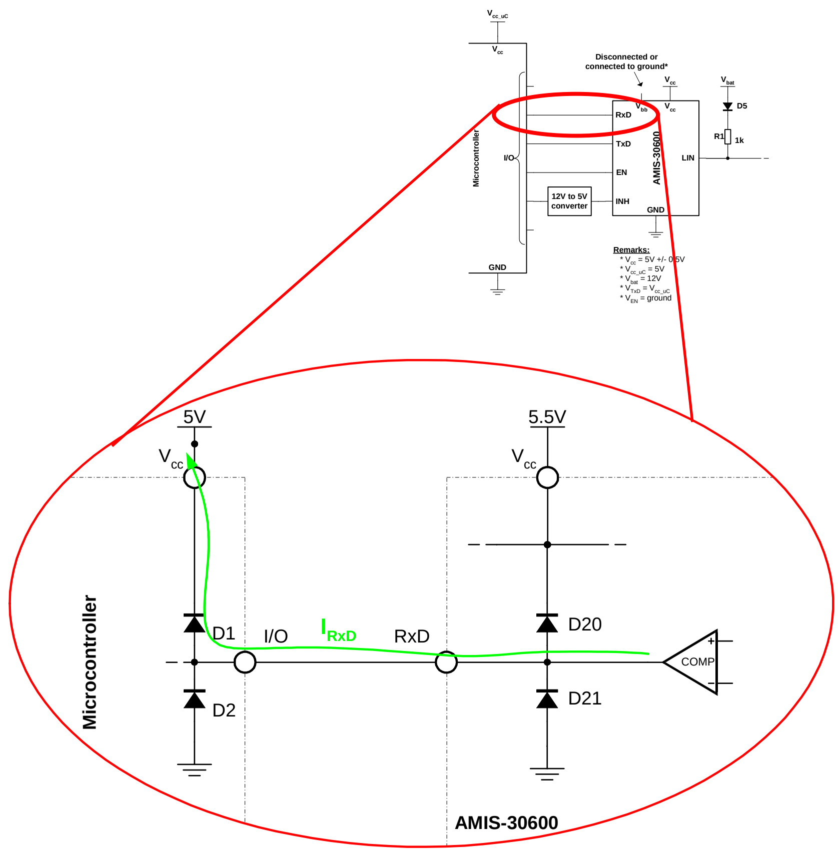

Figure 10: ESD Protection Diode D1 Conducts[7]

During our measurements, the current I_{RxD} was 36µA[8].

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 12V-to-5V 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 12V-to-5V converter) or to ground by 22k (V_{INH} = 0V).

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

[7] Figure displays set up where INH-pin is connected to microcontroller.
[8] Negative current means current is injected.

Table 1 shows the <u>maximum</u> current consumption for the different set ups (see Figure 1: Vbb Disconnected or Connected to Ground).

Table 1: Max. Power Consumption when V_{bb} is 12V, Disconnected or Connected to Ground

	V_{bb} = 12V			V_{bb} Disconnected		V_{bb} Connected to Ground	
	I_{cc} [uA][9]	I_{bat} [mA]	I_{bb} [mA]	I_{cc} [uA]	I_{bat} [mA]	I_{cc} [uA]	I_{bat} [mA]
INH-pin connected with microcontroller	-12 (Vcc = 4.5V) 100 (Vcc = 5.5V)	52	1.7	350 (Vcc = 4.5V) 470 (Vcc = 5.5V)	52[10]	420	52
INH-pin connected with ground	-12 (Vcc = 4.5V) 100 (Vcc = 5.5V)	52	2.2	350 (Vcc = 4.5V) 470 (Vcc = 5.5V)	52	400	52[10]

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).

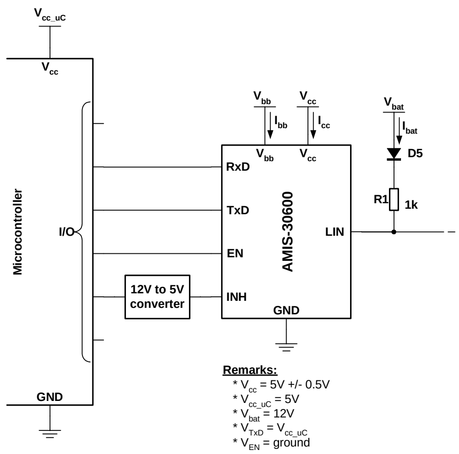

Figure 11: Current Consumption First Set-up

In Table 1, one can see that the current consumption of the AMIS-30600 (I_{cc}) is between –12µA and 100µA for V_{bb} = 12V. The reason I_{cc} is negative when V_{cc} is 4.5V is because V_{cc_uC} is 5V. When V_{cc} would be 5V, the current I_{cc} would be less than 1µA (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 52mA (V_{LIN} = -40V). This can also be calculated as the voltage drop over R1 (1kohm) 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).

[9] Positive current means injected current in V_{cc}-pin.
[10] V_{LIN} = -40V.

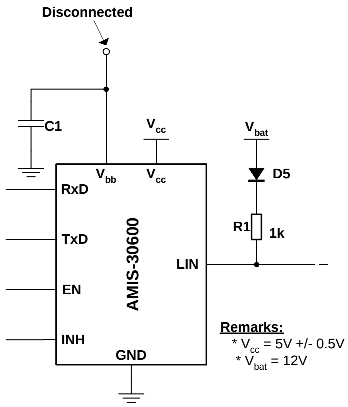

Figure 12: Decoupling Capacitor Present when V_{bb} is Disconnected

Intermediate conclusion:
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[11].

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.

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

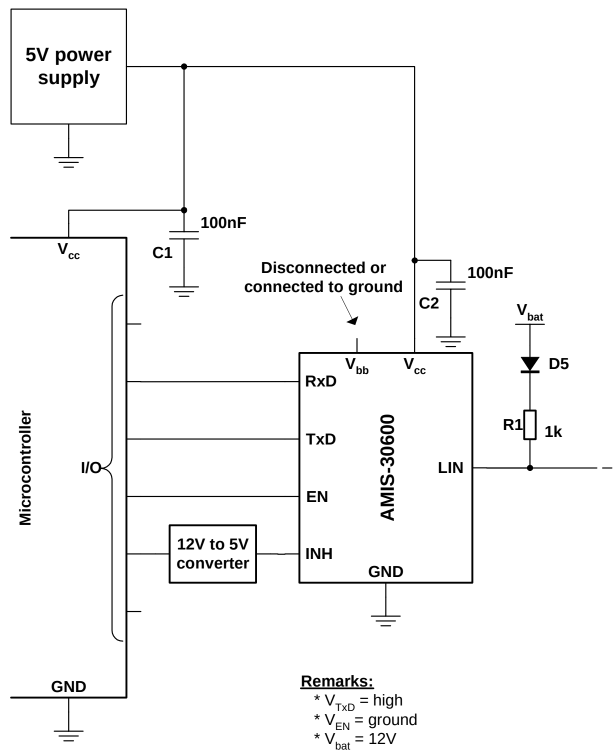

Figure 13: Use One Power Supply to Supply µC and AMIS-30600

5.2 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 450µA (V_{LIN} = -40V and V_{bb} disconnected or connected to ground).

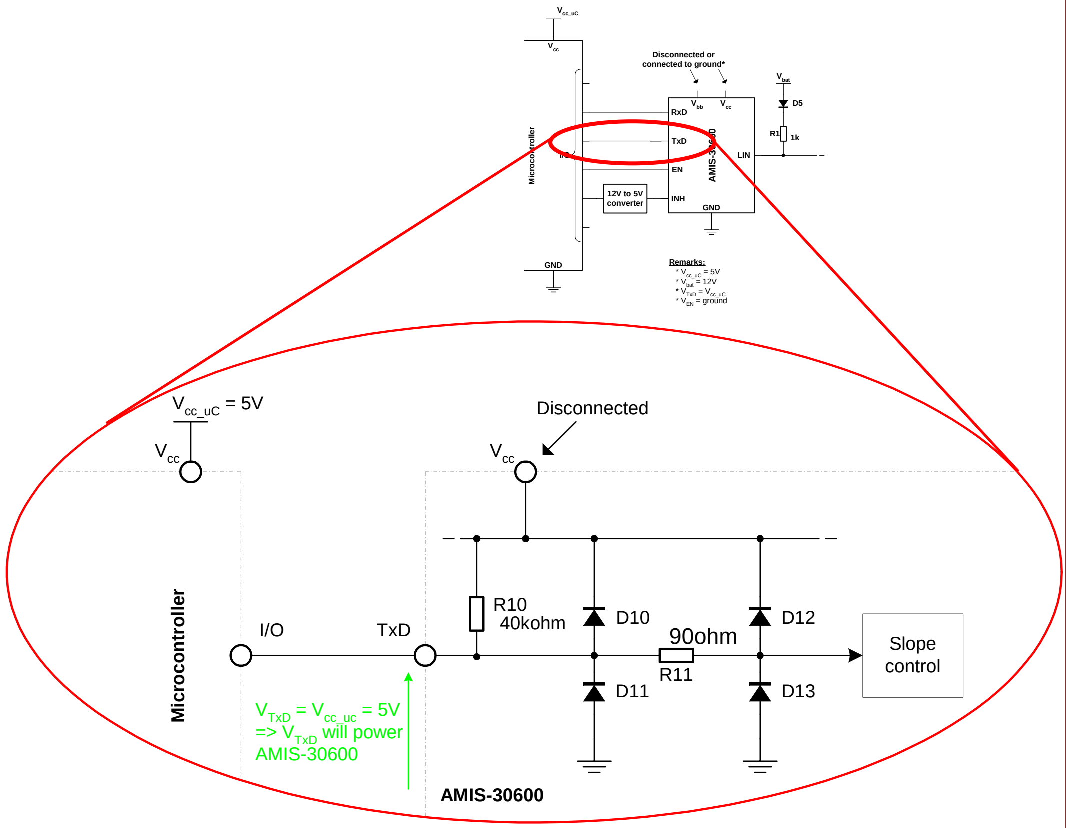

Figure 14: V_{TXD} will Power AMIS-30600 when V_{CC} is Disconnected[12]

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 5V (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 1µA. 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 ($-40V < V_{LIN} < +40V$). Similar, V_{cc} may not be connected to ground (see TxD-pin).

[12] Figure displays set up where INH-pin is connected to microcontroller.

INH-pin: The maximum voltage on the INH-pin when V_{cc} and V_{bb} are disconnected is +3.5V (V_{LIN} = +40V and INH-pin connected to 12V-to-5V converter). The minimum voltage is -500mV (V_{LIN} = -40V, INH-pin connected to 12V-to-5V converter or connected to ground). The maximum current measured at this pin is +/-20µA[13].

When V_{cc} is disconnected and V_{bb} connected to ground, the voltage on the INH-pin is 0V (INH-pin connected to 12V-to-5V 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 <u>maximum</u> battery current consumption I_{bat} for the different set ups.

Table 2: Max. Power Consumption when VCC is Disconnected or Connected to Ground

	I_{bat} [mA]			
	V_{bb} Disc.		V_{bb} to Ground	
	V_{cc} disc.	V_{cc} to ground	V_{cc} disc.	V_{cc} to ground
INH-pin connected with microcontroller	52[14]	N.A.	52[14]	N.A.
INH-pin connected with ground	52	N.A.	52	N.A.

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 0A. But because V_{TxD} is 5V (pulled high by the microcontroller), the microcontroller has to deliver the supply current for the AMIS-30600.

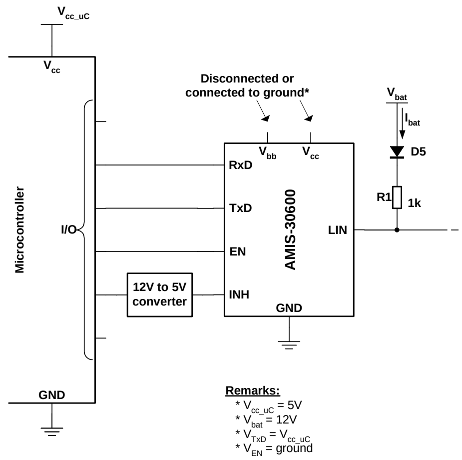

Figure 15: Current Consumption Second Set-up

[13] Negative current means current is injected.
[14] V_{LIN} = -40V

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.

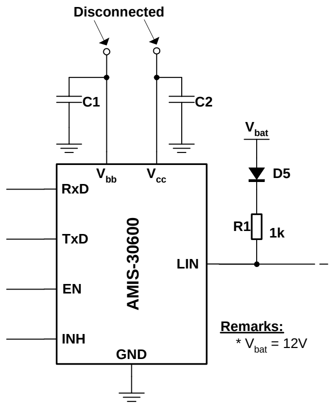

Figure 16: Decoupling Capacitor Present when V_{bb} and V_{cc} Disconnected

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 0A. 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 set up.

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 500µA) total power consumption.

One can see that the battery current I_{bat} is still high (max 52mA). To reduce this, one can try to disconnect the LIN pull-up resistor (see Section 5.3.

5.3 LIN Pull-up Resistor Disconnected (see Figure 3)

TxD-pin: Similar as without LIN pull-up resistor disconnected (see *5.2V_{cc} disconnected or connected to ground*) with the exception that the battery current consumption I_{bat} is 0A.

RxD-pin: Similar as without LIN pull-up resistor disconnected (see *5.2V_{cc} disconnected or connected to ground*) except that I_{bat} is 0A.

EN-pin: Similar as LIN pull-up resistor connected (see *5.2 V_{cc} disconnected or connected to ground*) except that I_{bat} is 0A.

INH-pin: Similar as without LIN pull-up resistor disconnected (see *5.2V_{cc} disconnected or connected to ground*) except that I_{bat} is 0A.

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

Intermediate conclusion:
One can disconnect the LIN pull-up resistor to reduce battery consumption. The consumed battery current is in all cases 0A which is significant lower than previous test (see *5.2 V_{cc} disconnected or connected to ground*).

6.0 Conclusion and Advised Application Schematic

To reduce the power consumption of the AMIS-30600 when disabled (V_{EN}= 0V), 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 pull-up resistor can be disconnected.

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

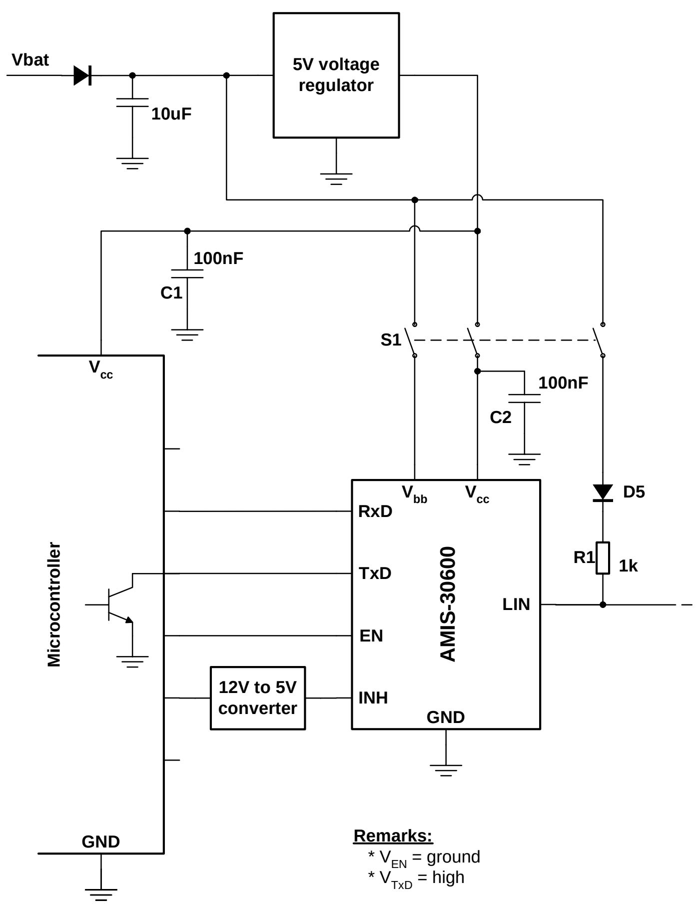

Figure 17: Advised Application Schematic

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[15].

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 0A[16] (-40V < V_{LIN} < +40V). Keep in mined that another node should pull the LIN-bus to 12V.

Applying a voltage on the LIN bus (-40V < V_{LIN} < +40V) will have no influence on the TxD-, RxD-, EN- and INH-pin. The current for these pins was always lower than 2µA 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 20µA (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 5V voltage regulator (where it's initially designed for). When the LIN transceiver goes to sleep mode (V_{EN} = 0V), INH-pin will switch of the 5V voltage regulator. Then the microcontroller can disconnect V_{bb} and the LIN pull-up resistor (S1). As long as V_{bb} is disconnected, the LIN transceiver will be in an off-state and will not disturb the network[17]. 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 5V 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.

[15] 5V voltage regulator has to stay within the operating range of the AMIS-30600 and the microcontroller.
[16] Power consumption microcontroller ignored and ideal 5V voltage regulator assumed.
[17] Keep in mind that when V_{bb} is disconnected, INH-pin cannot be used to detect a wake-up on the LIN bus (for this V_{bb} should be connected).

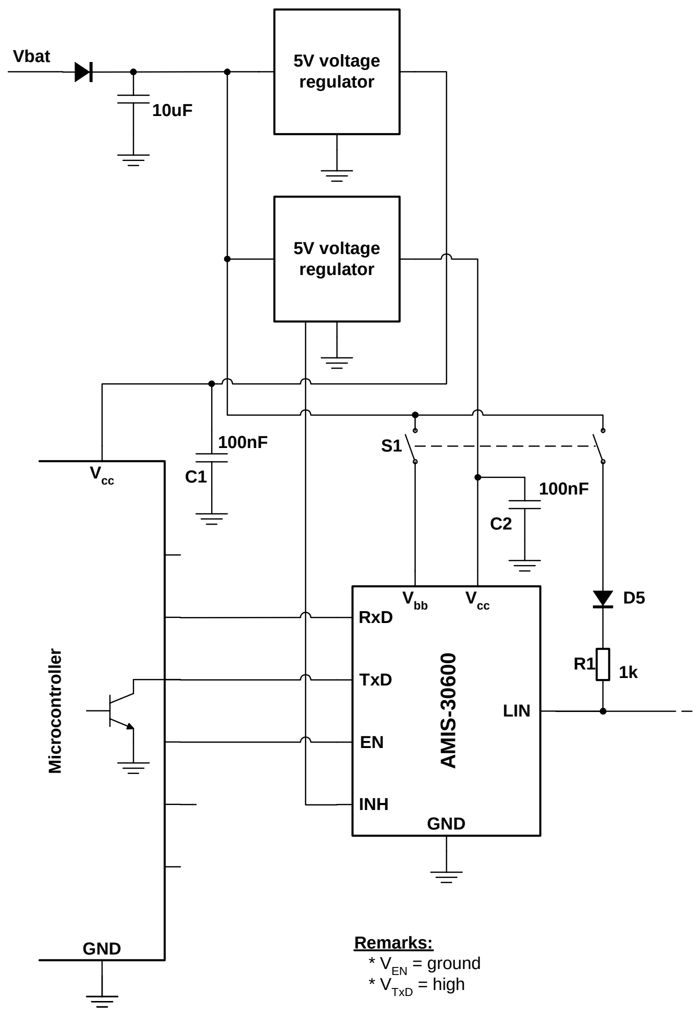

Figure 18: INH-pin Connected with 5V Voltage Regulator

In Figure 18, one can see that two 5V 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 5V 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 5V voltage regulators.

One could also use the INH-pin to disconnect the LIN pull-up 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 5V voltage regulator will be switched on and the pull-up resistor will be reconnected. The microcontroller can put the AMIS-30600 in normal mode by switching the EN-pin high.

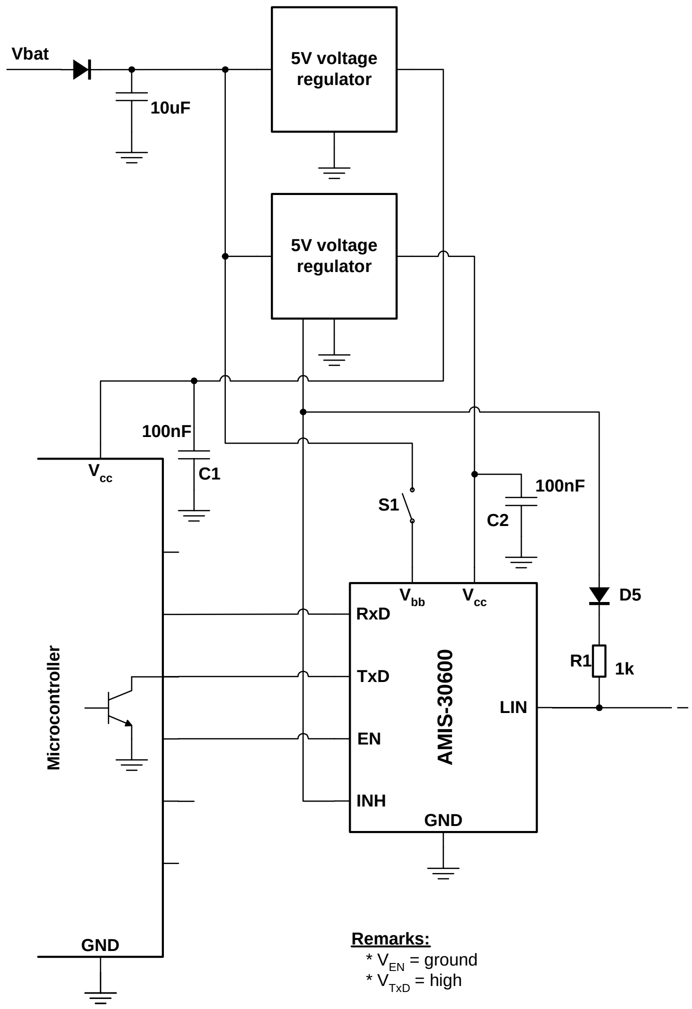

Figure 19: INH-pin used to Disconnect LIN Pull-up Resistor

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

One can see in Figure 18 and Figure 19 that the 12V-to-5V 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 pull-up resistor will be disconnected.

7.0 Addendum

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

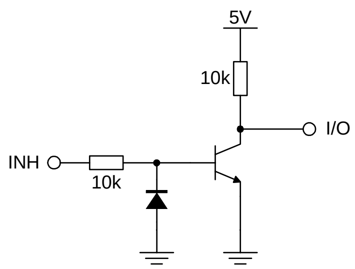

Figure 20: Simple 12V-to-5V Converter with Transistor

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

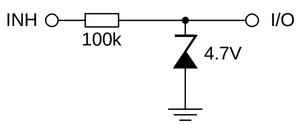

Figure 21: Simple 12V-to-5V Converter with Zenerdiode

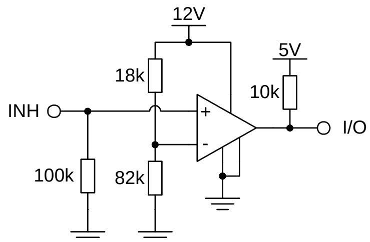

Figure 22: Simple 12V-to-5V Converter with Comoparator

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

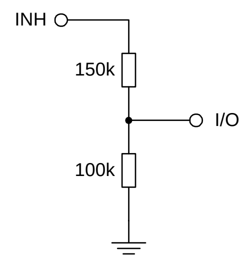

Figure 23: Simple 12V-to-5V Converter with Resistors

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

8.0 Company or Product Inquires

For more information about AMI Semiconductor's CAN/LIN transceivers, send an email to www.amis.com/sales.

For more information about AMI Semiconductor's products or services visit our Web site at http://www.amis.com.

9.0 Revision History

Table 3: Revision History

Revision	Date	Modification
2.0	Apr. 2005	Initial release
3.0	Sept. 2007	