

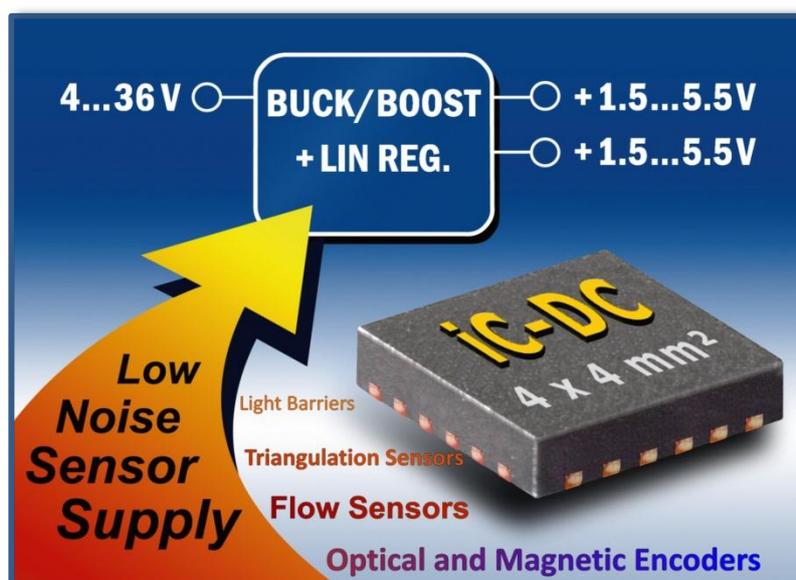
Integrated Analog and Digital Power Supply for Remote Sensors

Compact and decentralized electronic circuits such as controls, encoders, optical sensors, light barriers or laser modules are primarily supplied via long lines with a 24 V voltage in industrial applications. This voltage can fluctuate up to +/-50% and can be overlain by low frequency glitches and noise. In the field of sensor technology, however, high-precision analog circuits have to be supplied with a voltage as precise and glitch-free as possible. Digital circuit components and microcontrollers require supply voltage tolerances of less than +/-5% with a ripple of < 50 mV. Sensors with analog and digital circuit components however require two supply voltages. In modern sensors for example, high-precision analog circuits work together with microcontrollers or drivers with a switching capability of several 100 mA, such as IO-Link interface drivers [1] or RS422 line drivers. This combination can cause crosstalk, glitches at the supply voltage and/or ground displacements. The consequence arising from these different requirements is a clear split-up of the voltage supplies in the device.

This White Paper describes the design challenges, optimized converter architecture, layout hints to meet these requirements and examples of typical sensors.

Contents

- 1) [Separation of Analog and Digital Supply](#)
- 2) [Hybrid Converter Architecture for Split Supply Voltages](#)
- 3) [Converting Together, Supplying Separately](#)
- 4) [Split of the Supply Voltages in the PCB-Layout](#)
- 5) [Sensor Power Supply Examples](#)
 - 5.1 [Optical Encoder](#)
 - 5.2 [Thermal Flow Sensor](#)
- 6) [Summary](#)
- 7) [Literature](#)



1) Separation of Analog and Digital Supply

A classical approach for the split-up of supply voltages is the application of linear regulators. However, at an input voltage range of e.g. 12 to 36 V and output voltage of 5 V they have an undesirably high power dissipation. This can be reduced by the upstream of a DC/DC converter; however it increases the voltage supply's space requirement on the PCB. If two linear regulators with different output voltages are placed downstream, the power loss of the linear regulator with the lower output voltage is increased because it is not optimally supplied. An integrated solution is required in order to eliminate the disadvantages of this hybrid architecture. An integrated reverse polarity protection, as few as possible external passive elements, good EMV characteristics and monitoring of the input and output voltage with buffering at voltage failure are useful functions, which are increasingly demanded in modern devices.

A valuable approach is the integrated combination of a switching converter with two down-stream linear regulators each to split-up e.g. into a digital and an analog voltage supply, which are also independently adjustable.

2) Hybrid Converter Architecture for Split Supply Voltages

In order to minimize the losses in the linear regulators, a DC/DC converter should be capable of generating intermediate circuit voltages. This has been put into practice in the device [iC-DC](#). Figure 1 shows the basic architecture of the monolithic switching converter. Except for the passive LRC components, all active switches, diodes, as well as the oscillator are integrated on the chip.

The input voltage V_B can be supplied to the switching regulator via a reverse polarity protection circuit. With a single inductance the switching converter generates three intermediate voltages V_H , V_{H1} , and V_{H2} . The input voltage of linear regulators V_{H1} and V_{H2} is each approximately 400 mV higher than the corresponding output voltage. Due to its elegant architecture there is no explicit switching between boost and buck converter function. The input voltage can be smaller (min. 4 V) than the output voltage at the linear regulators (max. 5.5 V).

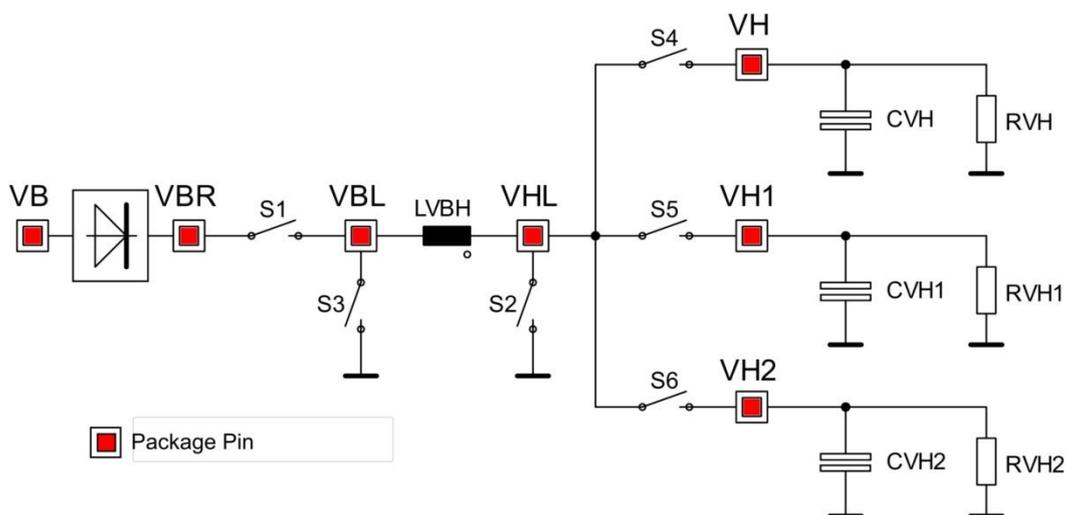


Figure 1: Switching Converter Architecture of [iC-DC](#)

This approach minimizes the losses in the linear regulators and the boost/buck converter's high efficiency results in an overall lower heat dissipation at input voltages of 4 to 36 V. All intermediate circuit voltages (VH, VH1, and VH2) are available as separate outputs in order to connect the required back-up capacitors of each typ. 3.3 μ F. The achieved efficiency is between 70 and 80 %, depending on the operating point. The converter's switching frequency is typ. 3 MHz and allows the application of small inductors of approx. 5 mm x 6 mm (LVBH = 22 μ H with $R_i < 1.1 \Omega$ and $I_{max} > 1 A$). The **iC-DC** is designed for a total current supply of up to 300 mA. The load current can be distributed to both outputs as desired.

3) Converting Together, Supplying Separately

The desired reduction of the space required in compact sensors demands a complete integration of the voltage supply. In addition to the boost and buck converters and the two linear regulators **iC-DC** features additional functions, which are shown in figure 2. Thus, the complete monitoring of input and output voltages is integrated. It monitors the input voltage at VBR and issues an error message to VBROK, if VBR falls below 2.9 V or exceeds 42 V.

A drop of the supply voltage can be detected via an autarky function: if the voltage at VB falls below the voltage at VBR, the difference (typ. 12 mV) is detected and a LOW signal at output NAUT is generated. A sufficiently high buffering capacity can give a microcontroller enough time to carry out e.g. a save power-down.

The linear regulators' output voltages VCC1 and VCC2 are monitored as well. In case of an overvoltage or undervoltage a LOW signal at V1OK or V2OK is generated. In order to supply circuits which require a defined fast rise or fall time of the supply voltage (e.g. EEPROM), there are two switched supply voltages POE1 and POE2. Only when the enable input voltages at VCC1/VCC2 are reached, outputs POE1 and POE2 are switched on. Both linear regulators VCC1 and VCC2 can be switched on or off via separate inputs (ENV1 and ENV2). With a stand-by function for the entire **iC-DC** the current consumption can be reduced. This allows a pulsed operation of sensors via a micro controller with wake up timer. The chip temperature of **iC-DC** is monitored as well. When exceeding a chip temperature of 150 °C, switches S1 to S6 are being deactivated and a LOW signal at output TOK is being generated.

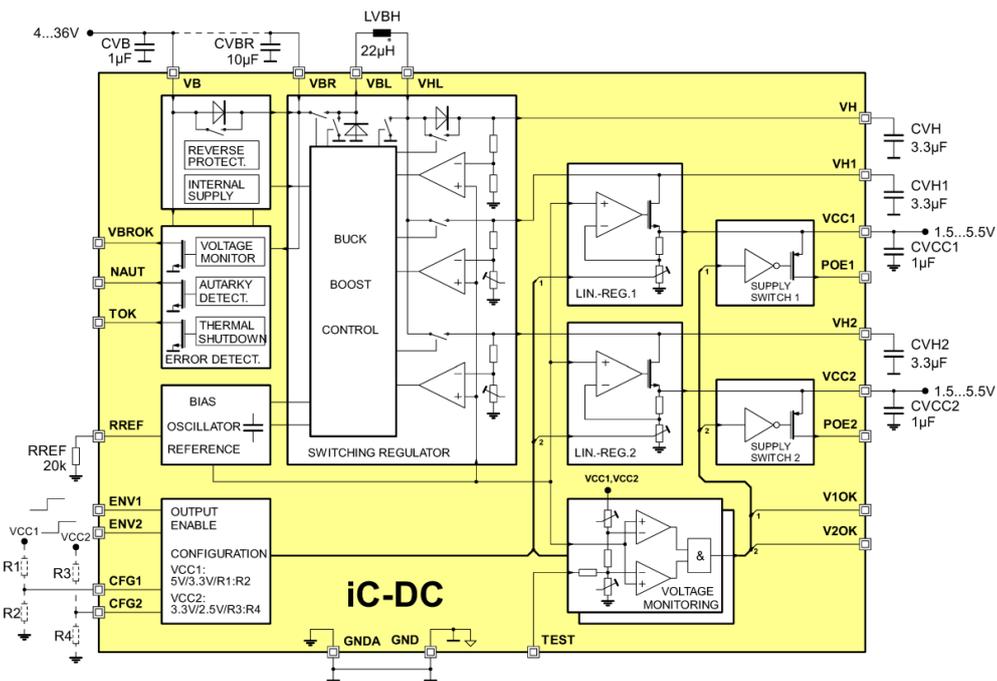


Figure 2: Integrated Voltage Supply for Sensors

For the supply of the analog circuit components either VCC1 or VCC2 can be used. This allows a general distinction between digital and analog voltage supply.

Figure 3 compares the output voltage's ripple of the linear regulator VCC1 (5 V) with its input voltage VH1 (output voltage of the switching converter). The ripple was measured at a load current of 50 mA and a band width of 20 MHz. Even using a comparatively small smoothing capacitor of 2 μ F (ESR < 1 Ω) the ripple is reduced by factor 10. In the frequency range of up to 1 kHz the PSRR is typ. 50 dB.

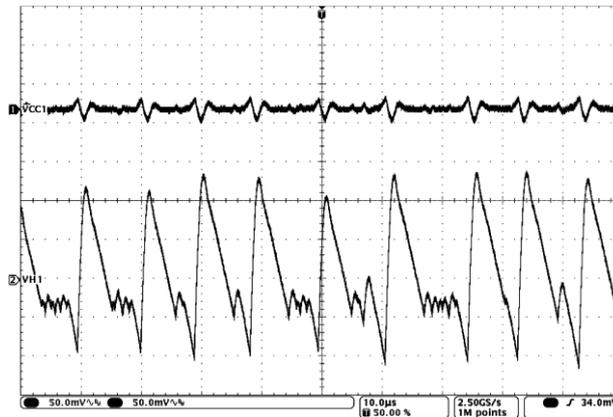


Figure 3: Reduction of the Ripple with the Aid of Integrated Linear Regulators

The output voltage VCC1 or VCC2 can be set from 1.5 to 5.5 V via a simple voltage divider at CFG1 resp. CFG2 or to 2.5, 3.3 or 5 V via logic level. The load regulation of voltages VCC1 and VCC2 is better than +/- 20 mV.

4) Split of the Supply Voltage in the PCB-Layout

An optimal PCB layout for an insulated analog and digital supply should preferably keep all undesirable glitches from the sensor signals. A few important applicable rules of thumb for the layout are:

- Keep digital ground signals (GND) and analog ground signals (GNDA) separated
- Connect GND and GNDA together at the entry point (system ground SGND)
- Interference block capacitors with small ESR are recommended (parallel connection of capacitors reduces ESR)
- Place the switch coil near by the converter's pins
- Route the blocking capacitors to the ground plane through vias and connect plus side directly to the IC supply

Figure 4 shows a typical layout for [iC-DC](#) with two supply voltages. The white dots in the picture represent vias to the ground plane below. The metal underside of the QFN24 package (U1) is also neutral point (SGND) for GND and GNDA. The blocking capacitors CVH, CVH1 and CVH2 of the intermediate circuit voltages VH, VH1 and VH2 are placed close to the iC-DC package. In order to block the adjustable output voltages VCC1 and VCC2, CVCC1 and CVCC2 are to be used. With the help of ceramic capacitor CVBR1 interference are blocked.

The [iC-DC's](#) integrated oscillator has an active frequency spread which additionally reduces the noise emission. All capacitors are connected to the ground plane through vias. A shielded coil should be used for LVBH because it has a lower noise emission than a simple coil.

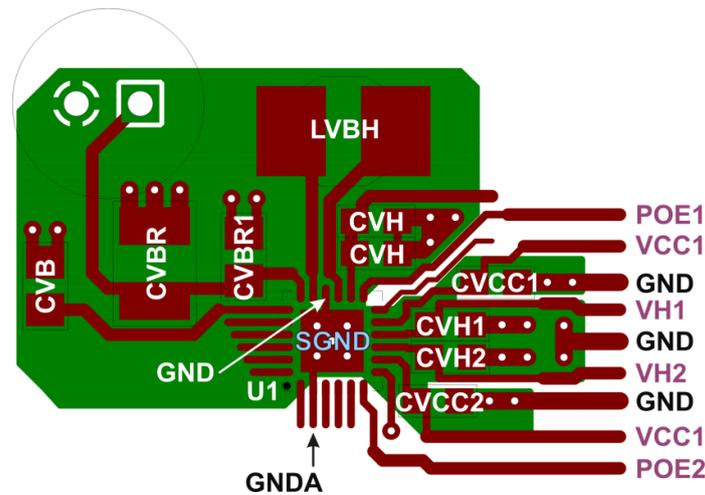


Figure 4: Layout for Two Supply Voltages

Information about layout and design can be requested [here](#).

5) Sensor Power Supply Examples

5.1) Optical Encoder

The example of a high-resolution optical encoder with 16-bit resolution illustrates the requirements for a typical voltage supply for sensors. Figure 5 shows the sensor system's block diagram with the encoder IC ([iC-LNG](#)), the micro controller, and the switching converter [iC-DC](#). The optical encoder [iC-LNG](#) works with an analog supply voltage of 4 to 5.5 V (photo diodes with amplifier, interpolator, LED regulation and sine/cosine output) and a digital supply voltage of 3.3 to 5.5 V (serial shift register, ABZ, SPI and parallel interface).

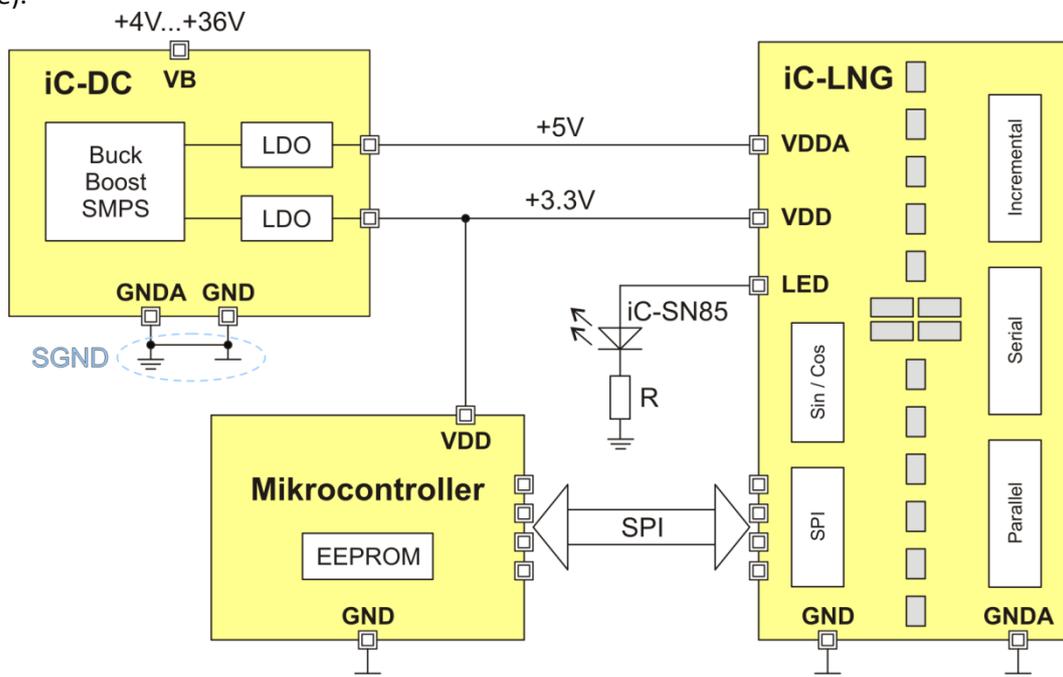


Figure 5: 16-bit Encoder with Split Voltage Supply for the Analog and Digital Component

The current consumption of iC-LNG with connected LED and micro controller is typically below 50 mA. By using iC-DC the current consumption from the power supply is reduced to 20 mA at a supply voltage of 24 V. The division into two supply voltages prevents a possible glitch of the analog circuit components, which can be caused e.g. through the switching of the digital IO ports.

5.2) Thermal Flow Sensor

Another sensor application containing precision analog and digital circuits is a thermal flow sensor or meter [3]. Figure 6 shows the system block diagram with the [iC-HO](#), the microcontroller and the [iC-DC](#) to convert the industrial 24 V to the sensor supply voltage needed. The [iC-HO](#) is a digital PI-heater control and contains several A/D- and D/A-converters with 11 to 16 bit resolution, three constant current sources. The analog output provides the measured flow sensor value. Control of the [iC-HO](#) is achieved via the SPI interface. In this case both outputs of the [iC-DC](#) are set to +5V. One +5V supply for the digital part share and the second supply for the precision analog sections.

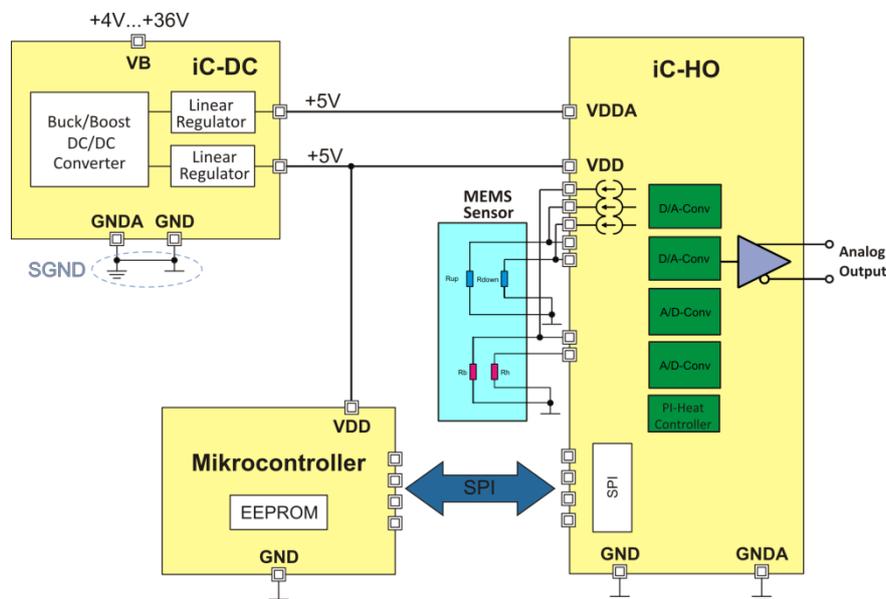


Figure 6: Thermal Flow Sensor with Digital and Analog Supply

6) Summary

The combined voltage supply of analog and digital ICs in high-precision and mostly compact sensors requires new concepts for the voltage converter architecture. Complete, integrated solutions, such as the hybrid boost/buck converter [iC-DC](#) support the consistent isolation of the analog and digital voltage supply and perform the complete power management in typical sensor applications. For IO-Link sensors this hybrid architecture has also been implemented in the [iC-GF](#) [1] transceiver with the capability to supply two independent voltages with up to 50 mA, while for low end sensors the [iC-DXC/DXC3](#) is using only one linear regulator to supply +5V or +3.3V with 10 mA.

7) Literature

- [1] Dr. David Lin, Dipl.-Ing. Uwe Malzahn, Dipl.-Ing. Álvaro Pineda Garcia, „PNP/NPN/PP or IO-Link?“, [EETimes Europe 2/2012](#)
- [2] Dipl.-Ing. Bernd Schrörs, Dipl.-Ing. Marko Hepp, [Fast optical distance sensing through System-on-Chip integration \(EDN - 09/2012\)](#)
- [3] Dipl.-Ing. Marko Hepp, Dipl.-Ing. Bernd Schrörs, [MEMS sensor signal conditioning for a thermal flow meter \(EE Times Europe - 03/2013\)](#)

About iC-Haus

iC-Haus GmbH is a leading, independent German manufacturer of standard iCs (ASSP) and customized ASiC semiconductor solutions with worldwide representation. For more than 25 years the company has been active in the design, production, and sales of application-specific iCs for industrial, automotive, and medical applications.

The iC-Haus cell libraries in CMOS, bipolar, and BCD technologies are specifically suited to realize the design of sensor, laser/opto, and actuator ASiCs, amongst others. The iCs are assembled in standard plastic packages or using the iC-Haus chip-on-board technology to manufacture complete microsystems, multichip modules, and optoBGA/QFN in conjunction with sensors.

Further information is available at <http://www.ichaus.com>