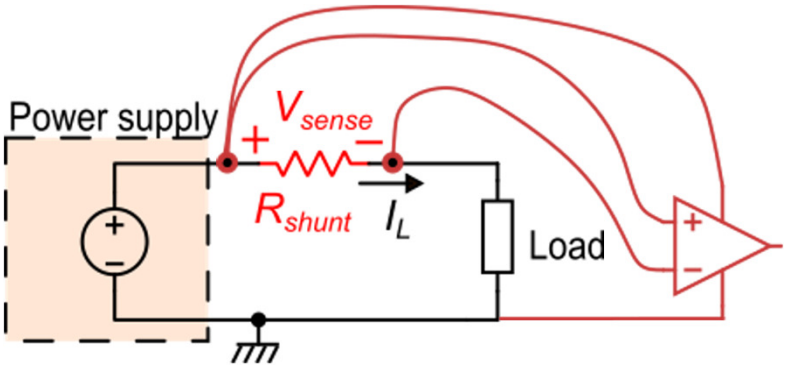
# Hazards due to unwanted coupling with high voltage sources

Hazards

- For the sensor system (risk of permanent damage)
- Risk for humans (injuries or death)

# Premise: *resistive current sensing* in power systems

**High-side** current sensing



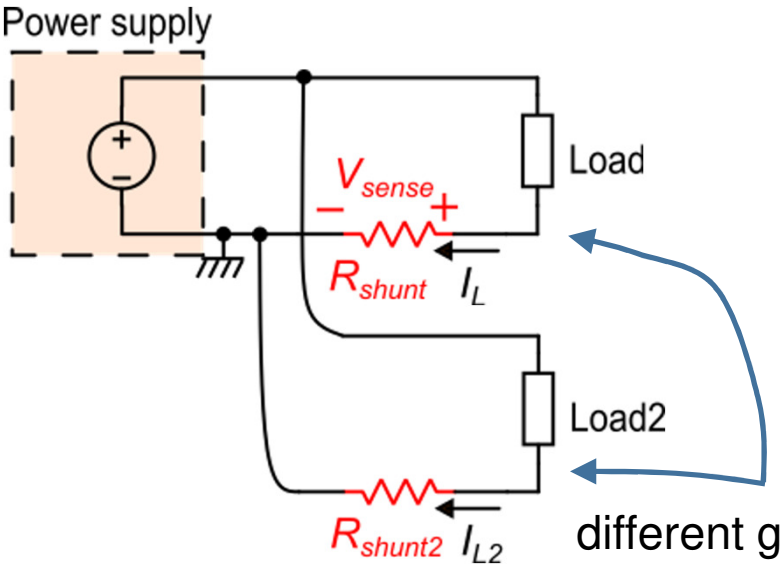

$$V_{sense} = I_L R_{shunt}$$

For negligible power loss:
$V_{sense}$ ~ mV

Amplification is needed

Input $V_{CM} \cong V_{sup}$
Very high CMRR is required if $V_{sup}$ has large variations

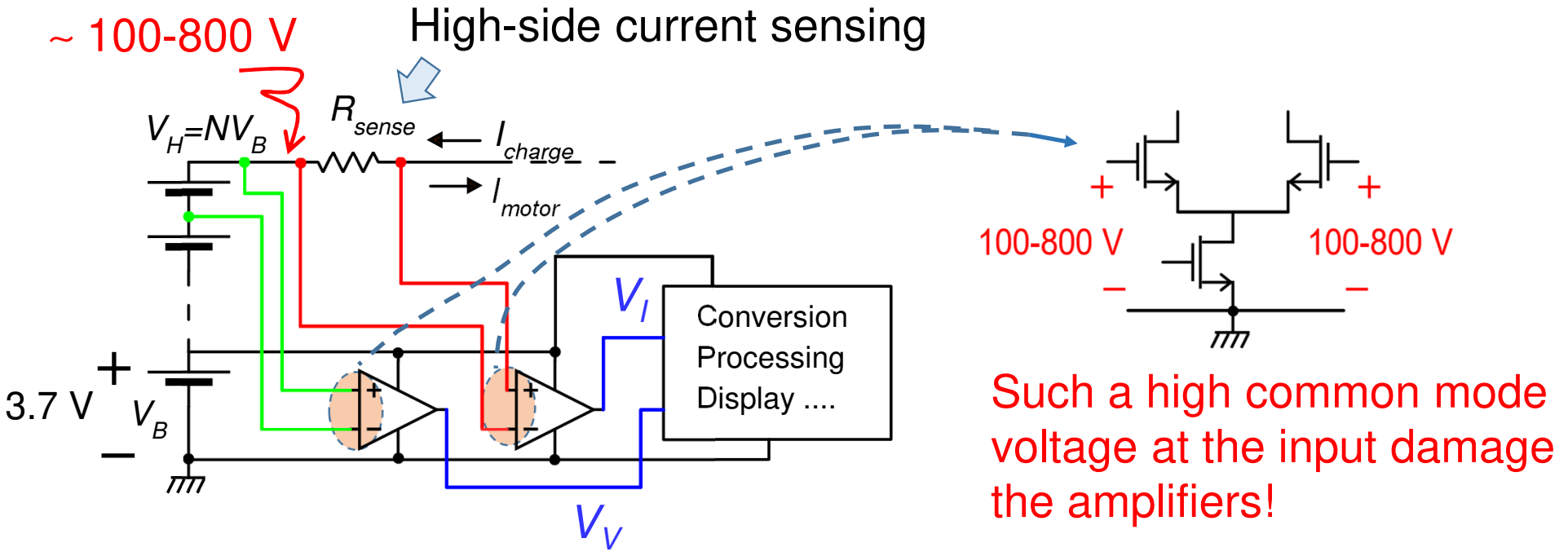
**Low-side** current sensing




+) Amplifier input $V_{CM} \cong 0$
-) Load gnd is not power supply *gnd*
-) Current sensing of independent loads cause gnd voltage differences

# Risk for the sensor system

Voltage and current sensing in battery packs for e-vehicles

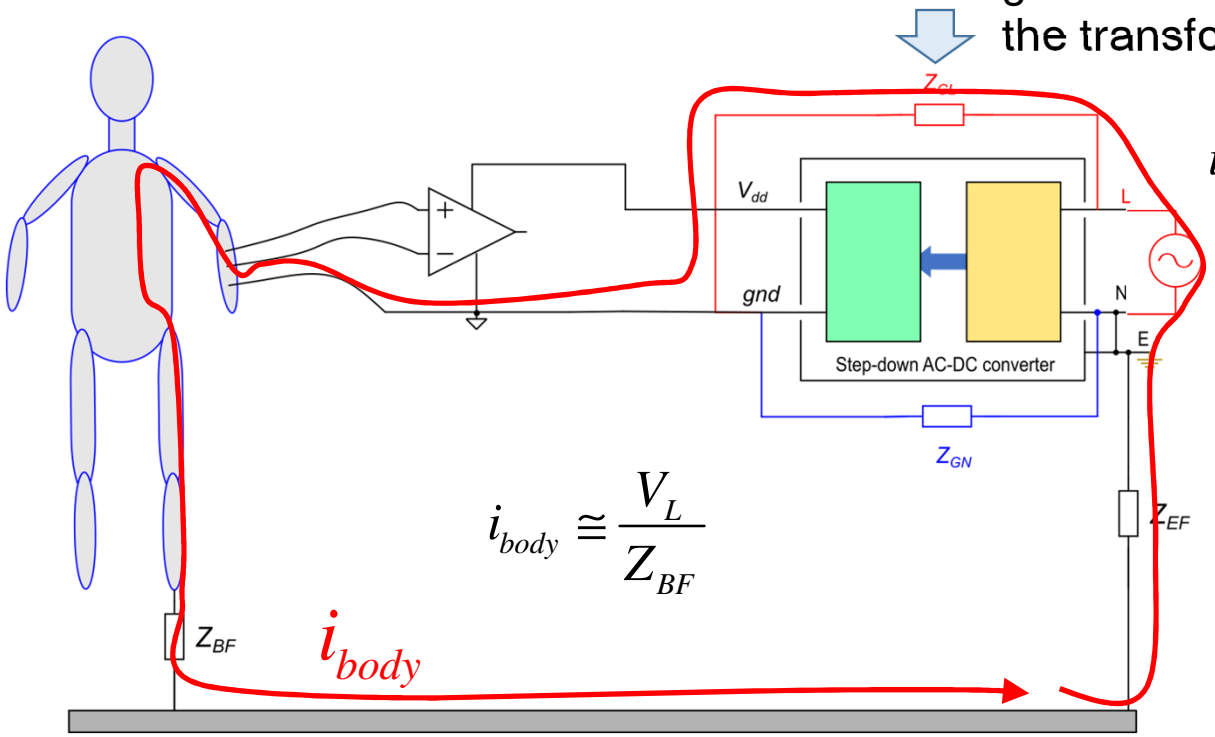



Goal: monitor the current through the battery and the voltage of individual cells for State-of-Charge estimation.

# Hazards to humans

Case 1: AC powered biomedical apparatus, electrically connected to the patient.

Let us suppose that this impedance gets much smaller due to a failure in the transformer insulation.




$$i_{body} = \frac{V_L}{Z_{BF} + Z_{GL} + Z_{EF}}$$

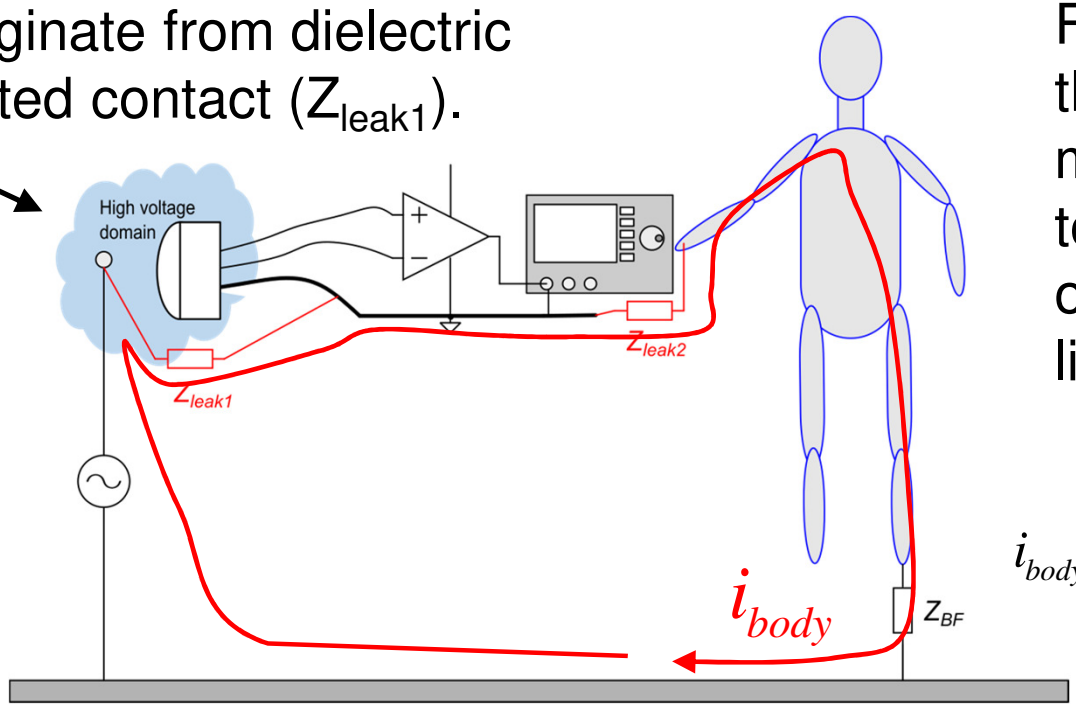
$$i_{body} \cong \frac{V_L}{Z_{BF}}$$

Depending on $Z_{BF}$, a large current may pass through the body. A current that passes through the heart is potentially fatal.

# Hazards to humans

Case 2: Sensing systems with possible continuity with a high voltage domain.

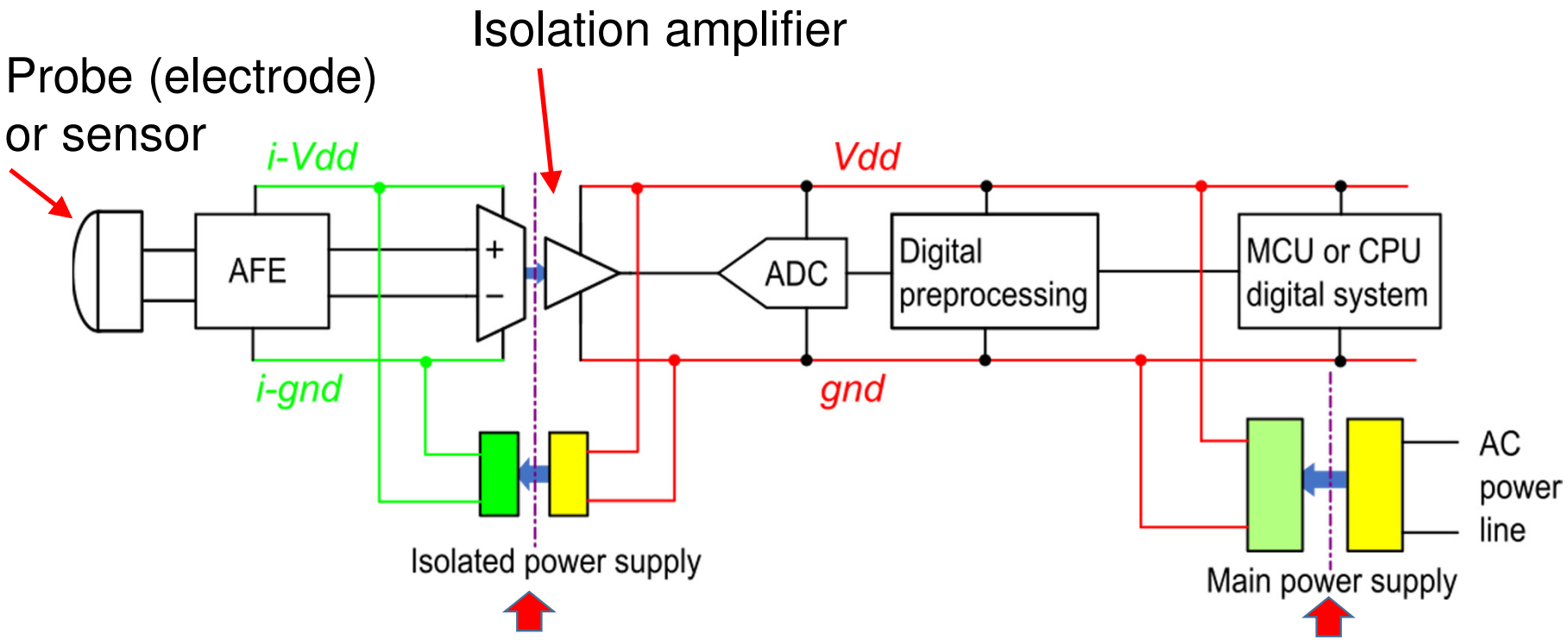
The sensor is isolated from conductors of the high voltage domain, but a leakage impedance may originate from dielectric failure or an unwanted contact ($Z_{leak1}$).




From the operator side, the front panel control may lose insulation due to wearing or presence of moisture / accidental liquid pouring

$$i_{body} = \frac{V_L}{Z_{BF} + Z_{leak1} + Z_{leak2}}$$

# Isolation approach 1: Isolation Amplifier




Double protection concept: this is a strict requisite in biomedical instrumentation

# Techniques for analog signal insulation

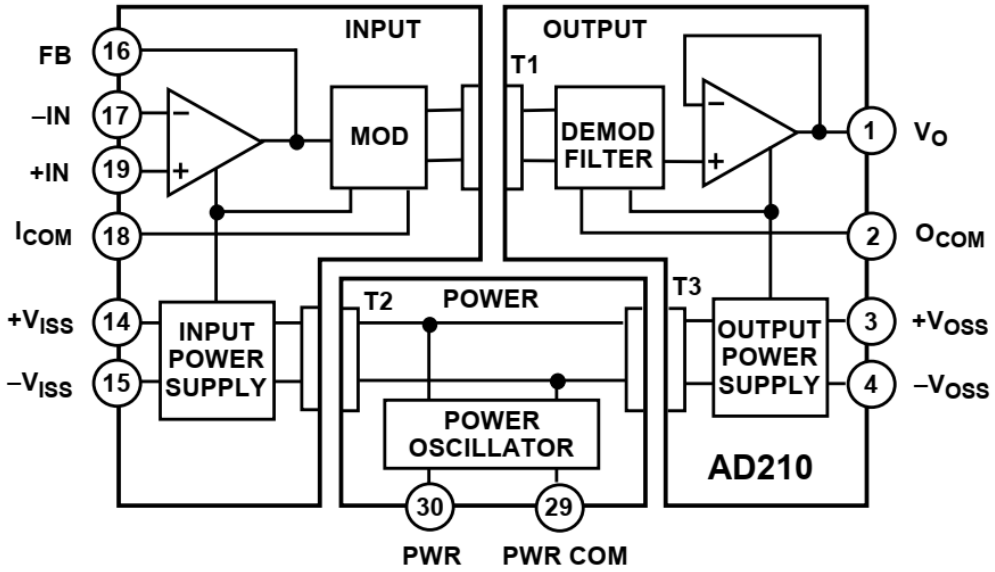
- ❑ Transformer coupling
- ❑ Optical Coupling
- ❑ Capacitive Coupling

Example of transformer coupling: the AD210

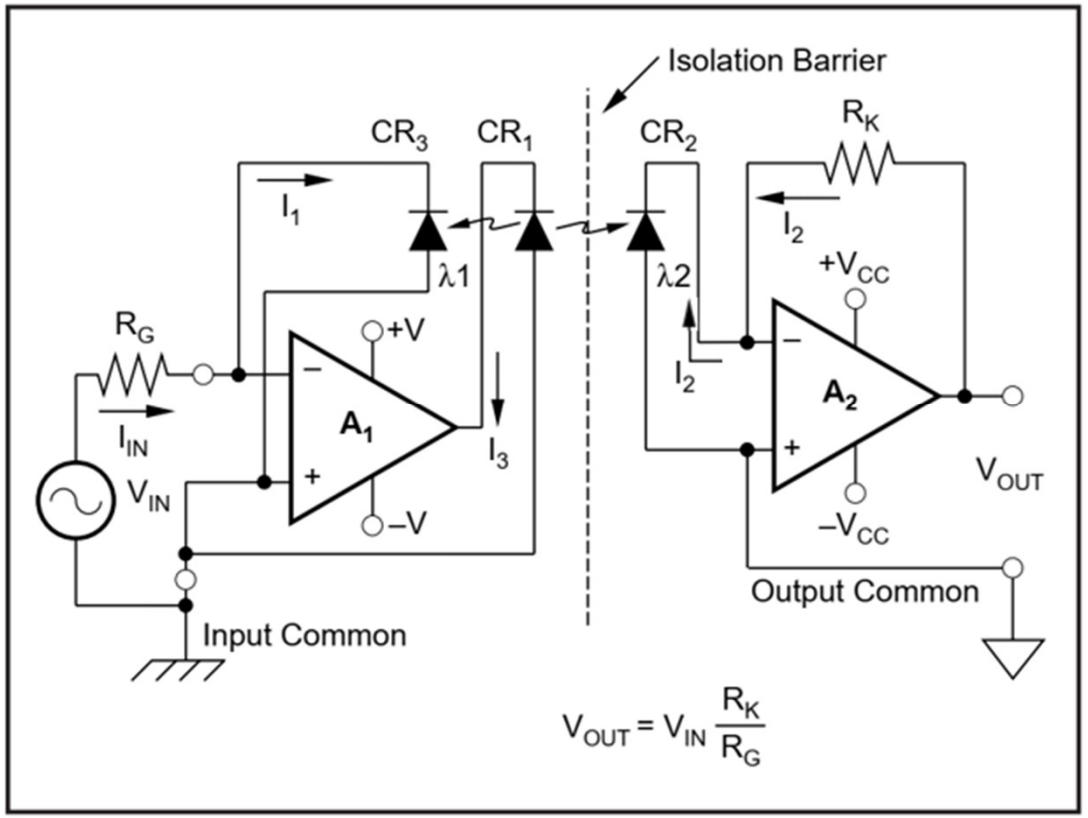
**FEATURES**
**High CMV Isolation: 2500 V rms Continuous**
**±3500 V Peak Continuous**
**Small Size: 1.00" × 2.10" × 0.350"**
**Three-Port Isolation: Input, Output, and Power**
**Low Nonlinearity: ±0.012% max**
**Wide Bandwidth: 20 kHz Full-Power (-**
**Low Gain Drift: ±25 ppm/°C max**
**High CMR: 120 dB (G = 100 V/V)**
**Isolated Power: ±15 V @ ±5 mA**
**Uncommitted Input Amplifier**

**APPLICATIONS**
**Multichannel Data Acquisition**
**High Voltage Instrumentation Amplifi**
**Current Shunt Measurements**
**Process Signal Isolation**


**FUNCTIONAL BLOCK DIAGRAM**



# Principle of analog optical coupling




## Example: Broadcom ACNT-H79A

An optical link is marked by strong non-linearity. It can be used in an open-loop scheme only to transmit digital signals.

For analog signals, a feedback scheme can be used, as in the figure. The LED $CR_1$ is coupled in a symmetrical way to photodetectors $CR_3$ and $CR_2$, thus:

$I_1 = I_2$ (photocurrents)

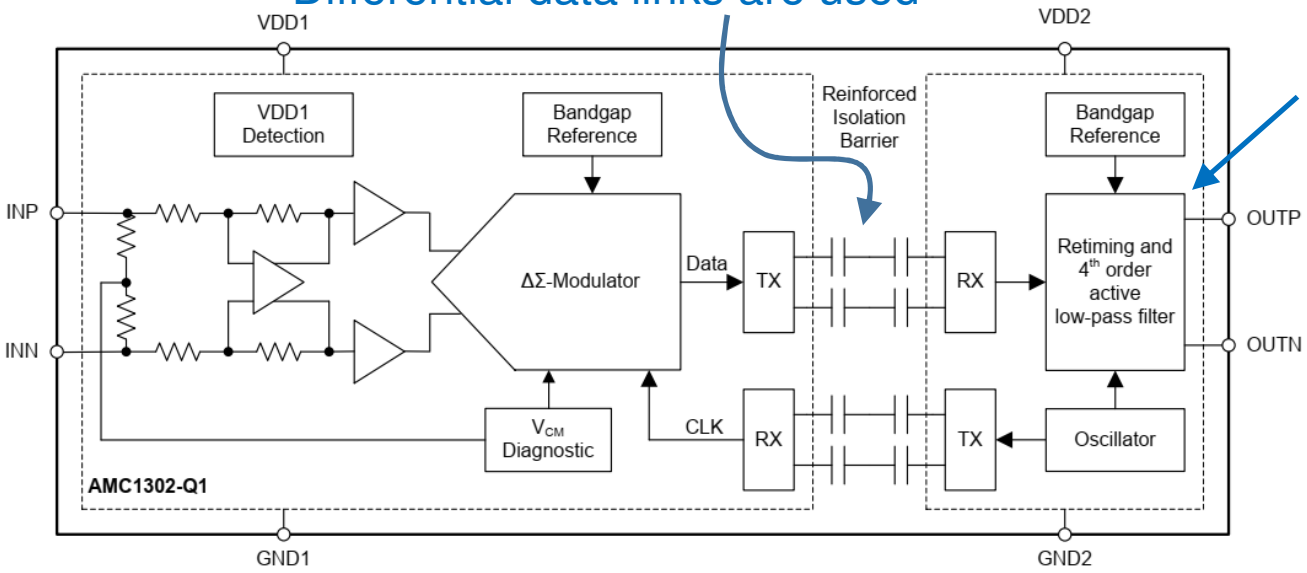
$I_1 = I_{IN} = \frac{V_{IN}}{R_G}$ virtual short circuit due to optical feedback at $A_1$.

$$V_{OUT} = I_2 R_K = V_{IN} \frac{R_K}{R_G}$$

# Isolation amplifier with capacitive coupling

Data that cross the barrier are digital (bitstream).
Differential data links are used

Data are converted back to analog by filtering.



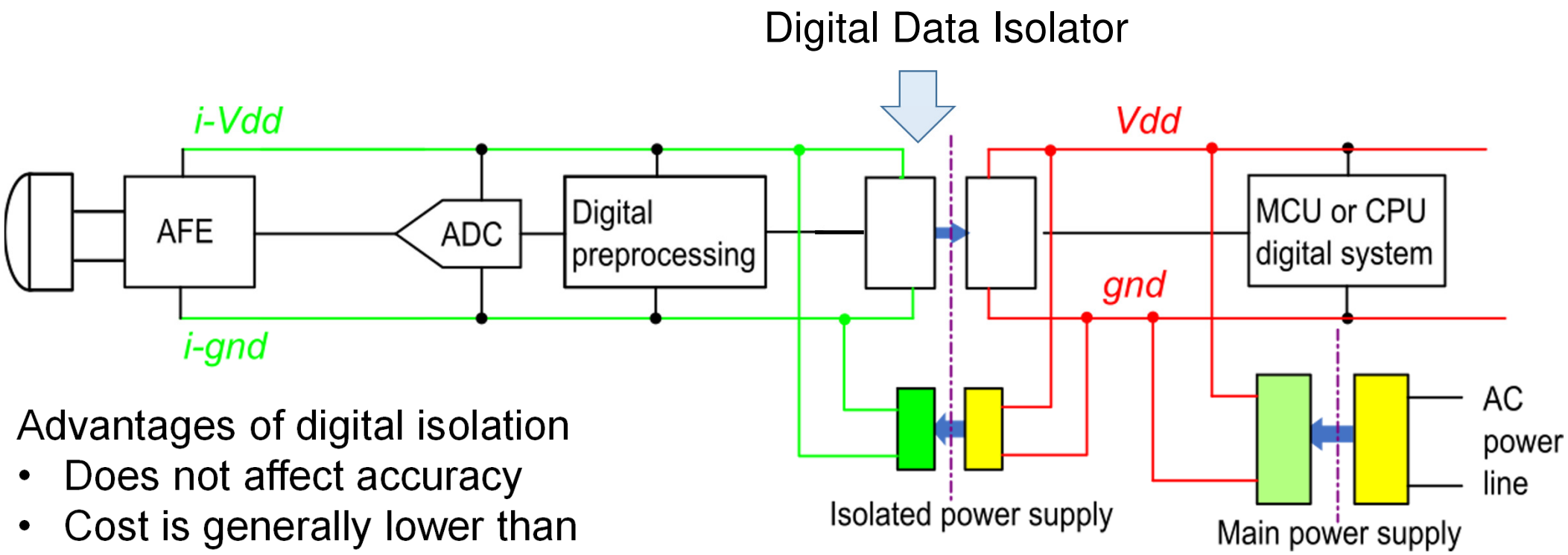

**AMC1302-Q1**

## 2 Applications

- Shunt-Resistor-Based Current Sensing In:
  - Onboard Chargers (OBC)
  - DC/DC Converters
  - Traction Inverters
  - Battery Management Systems (BMS)

| **DIN V VDE V 0884-11 (VDE V 0884-11): 2017-01 (2)** | | | | |
|---|---|---|---|---|
| $V_{IORM}$ | Maximum repetitive peak isolation voltage | At AC voltage | 2121 | $V_{PK}$ |
| $V_{IOWM}$ | Maximum-rated isolation working voltage | At AC voltage (sine wave); see Figure 4 | 1500 | $V_{RMS}$ |
| | | At DC voltage | 2121 | $V_{DC}$ |

# Isolation approach 2: Isolated Digital Link




Advantages of digital isolation

- Does not affect accuracy
- Cost is generally lower than analog
- Size is also generally smaller

Digital isolators are based on two principles:
(1) Optical (photocouplers) (2) Capacitive

# Example of digital data isolator: I2C isolator

4 channels are necessary because each one of the two I2C lines is bidirectional

Texas Instrument **ISO1640,**

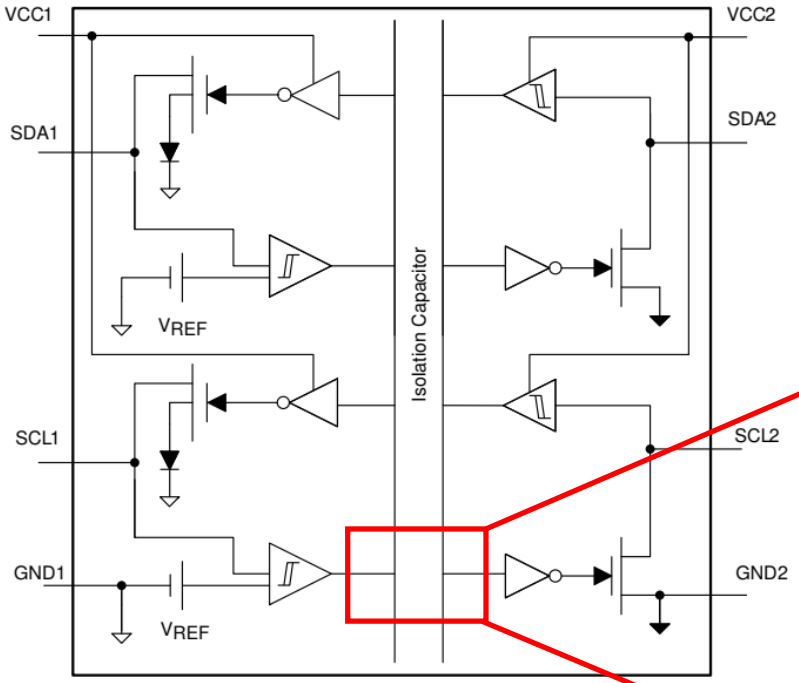
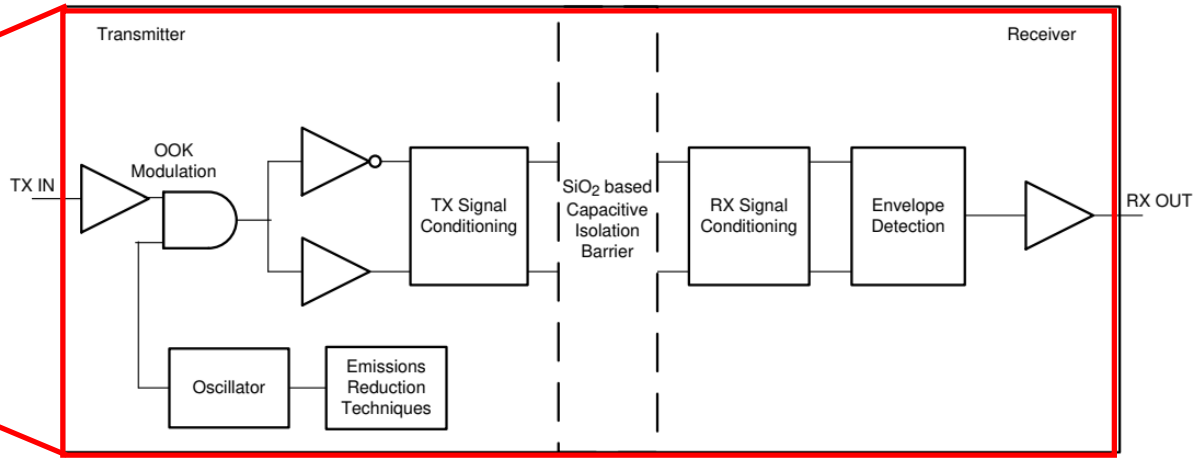



**Figure 8-1. ISO1640 Block Diagram**

Digital data are modulated by a high frequency carrier (on-off modulation (on-off keying, OOK) and transmitted across the barrier through a capacitive barrier.



# Example of isolated power supply

RECOM REM10 (10 W)
Medical compliant

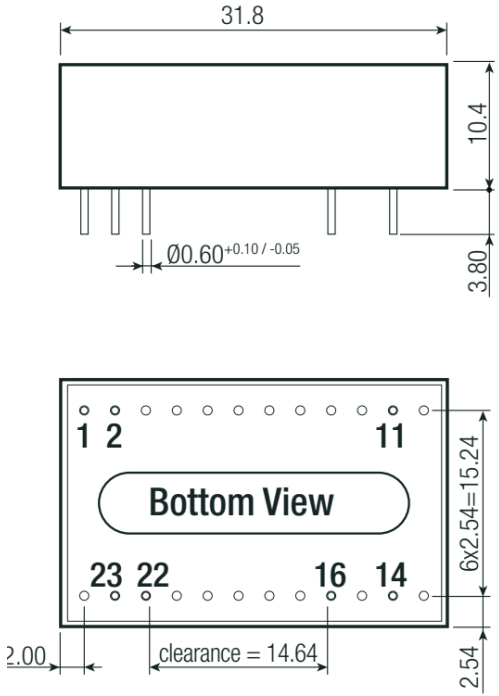
Isolation voltage: 5 kV

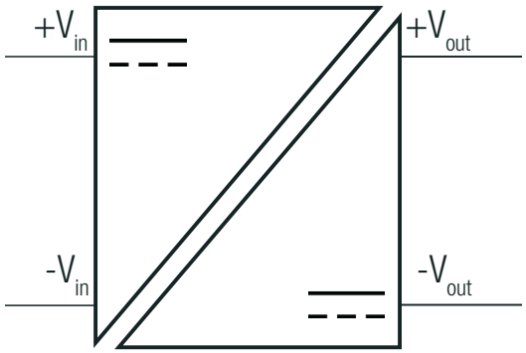

**Pin Connections**

| Pin # | Single | Dual |
|---|---|---|
| 1 | CTRL* | CTRL* |
| 2 | -Vin | -Vin |
| 11 | NC | -Vout |
| 14 | +Vout | +Vout |
| 16 | -Vout | Com |
| 22 | +Vin | +Vin |
| 23 | +Vin | +Vin |

* If the CTRL option is not chosen, Pin 1 will be absent

For standby mode




Simbolo