Intelligente Sensoren

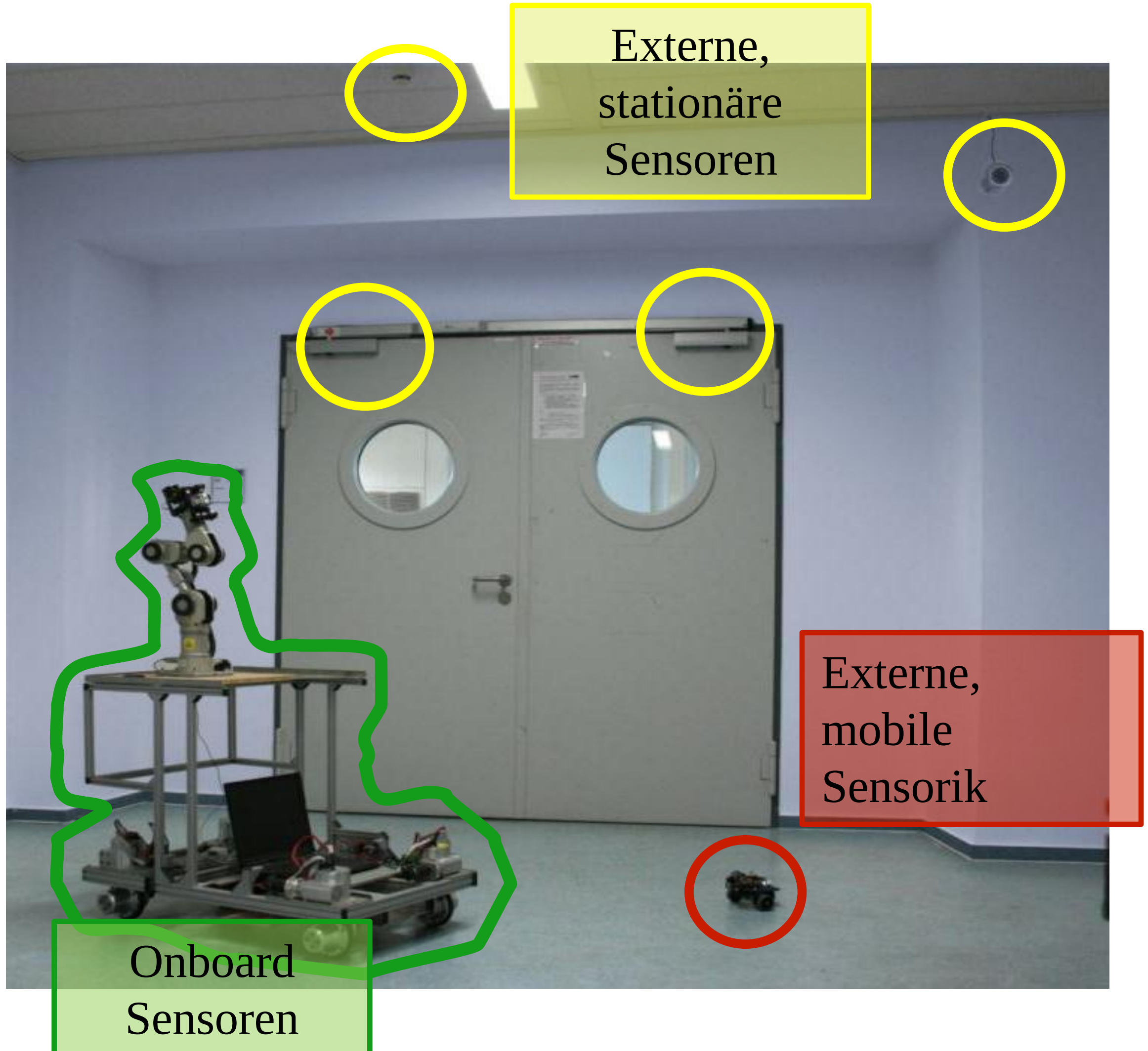
Warum überhaupt ?

Szeanrio:

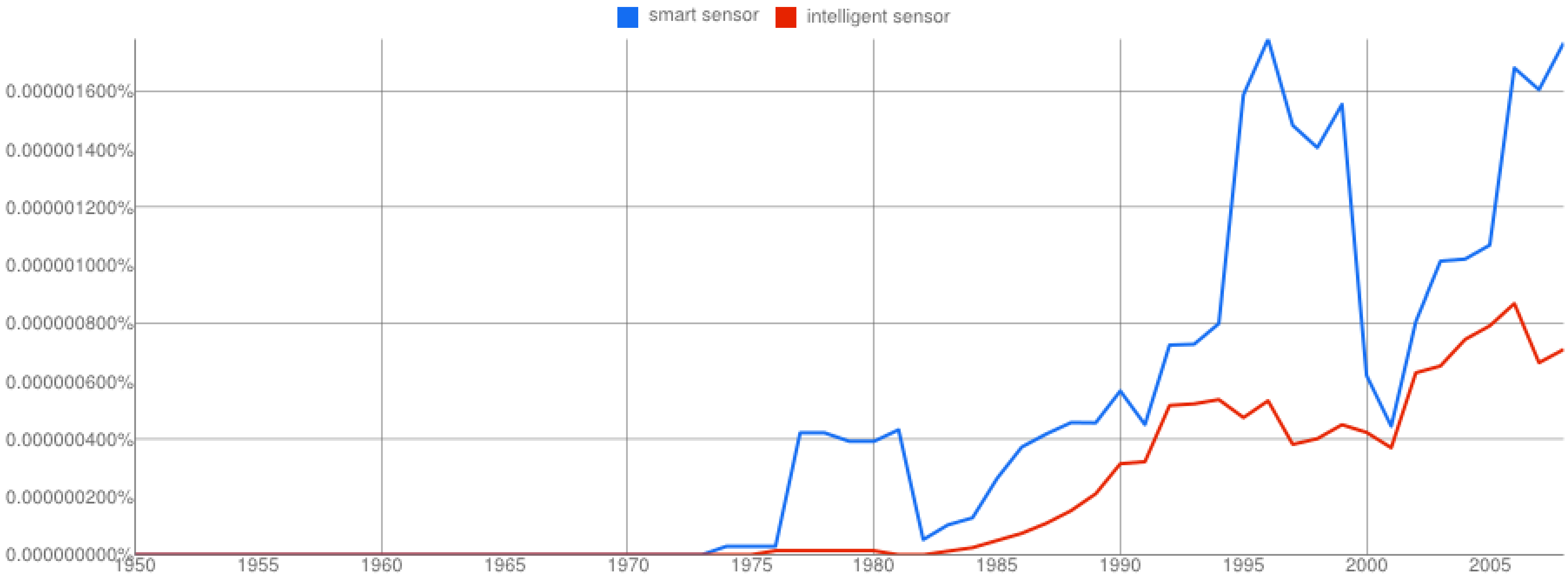
- Adaptive Umgebungs-erfassung in intelligenten Umgebungen
- Steigerung der Wahrnehmungsgüte durch die Ausnutzung externer Sensorik

Herausforderungen:

1. Datenaustausch
2. Dateninterpretation
3. Datenvalidierung

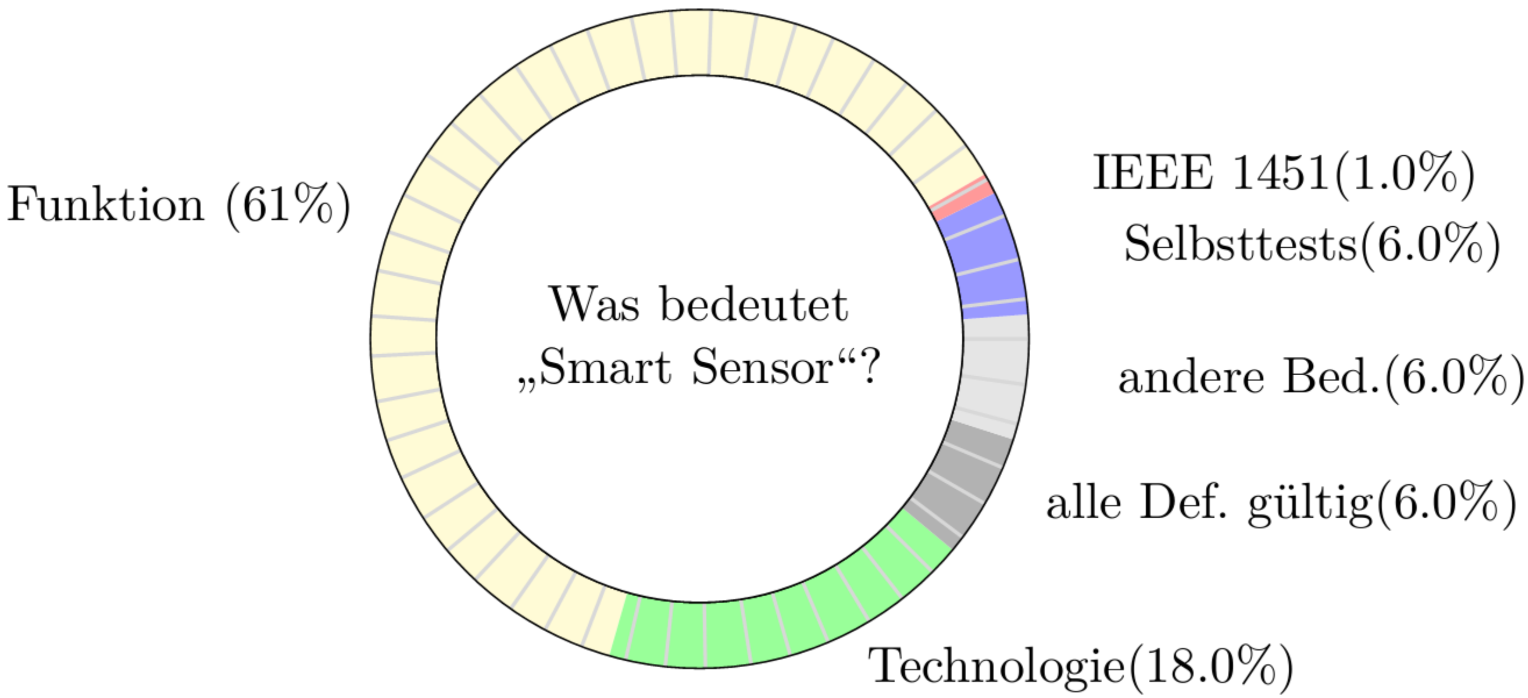


Entwicklung



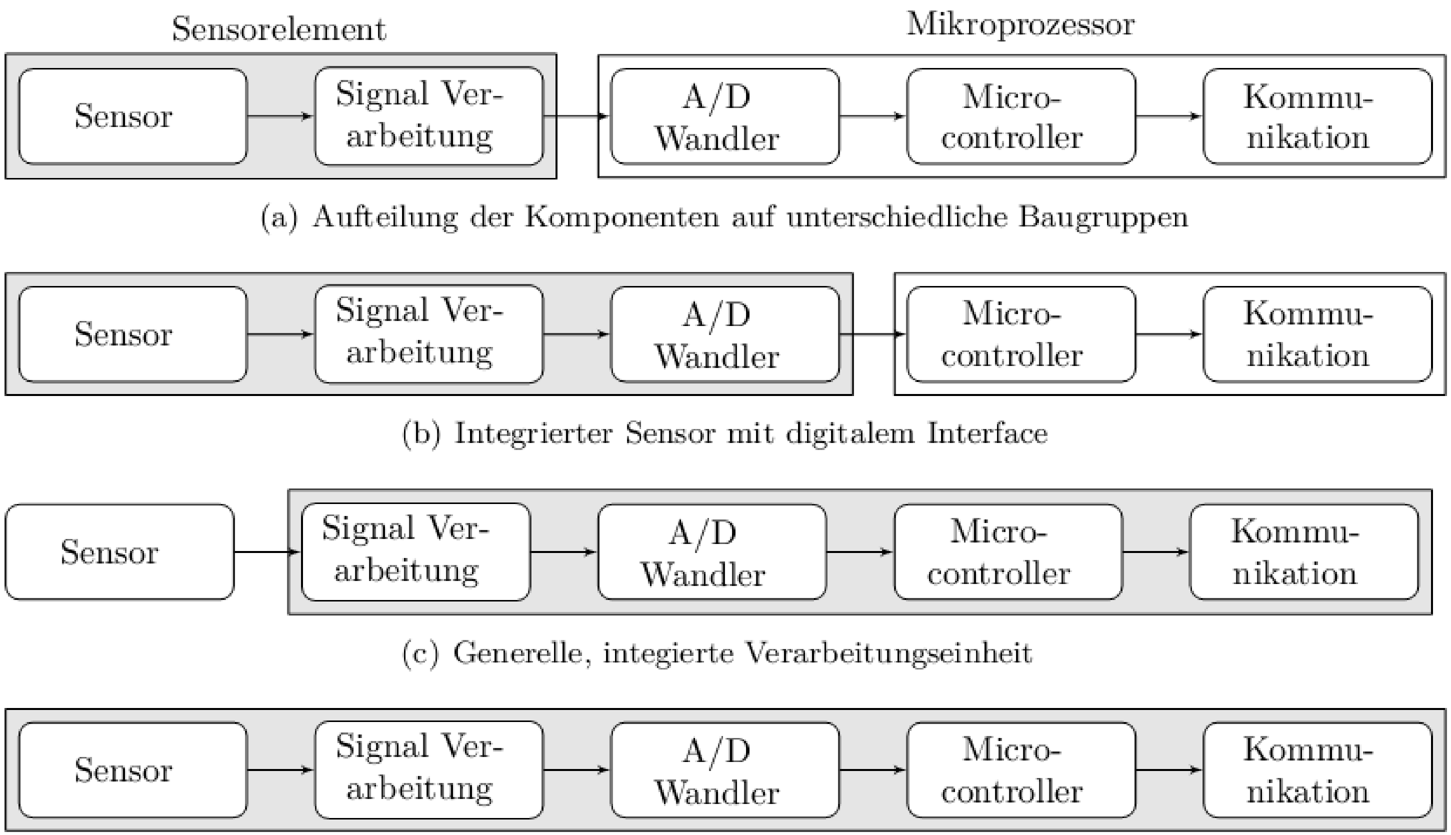
Google Ngram View für „Smart Sensor“, „Intelligent Sensor“

Sichtweisen



International Frequency Sensor Association. *Internetumfrage - What does it mean „smart sensor“?* available at http://www.sensorsportal.com/HTML/DIGEST/E_27.htm (8.04.2011). 2009.

Strukturelle / Technologie-Sicht



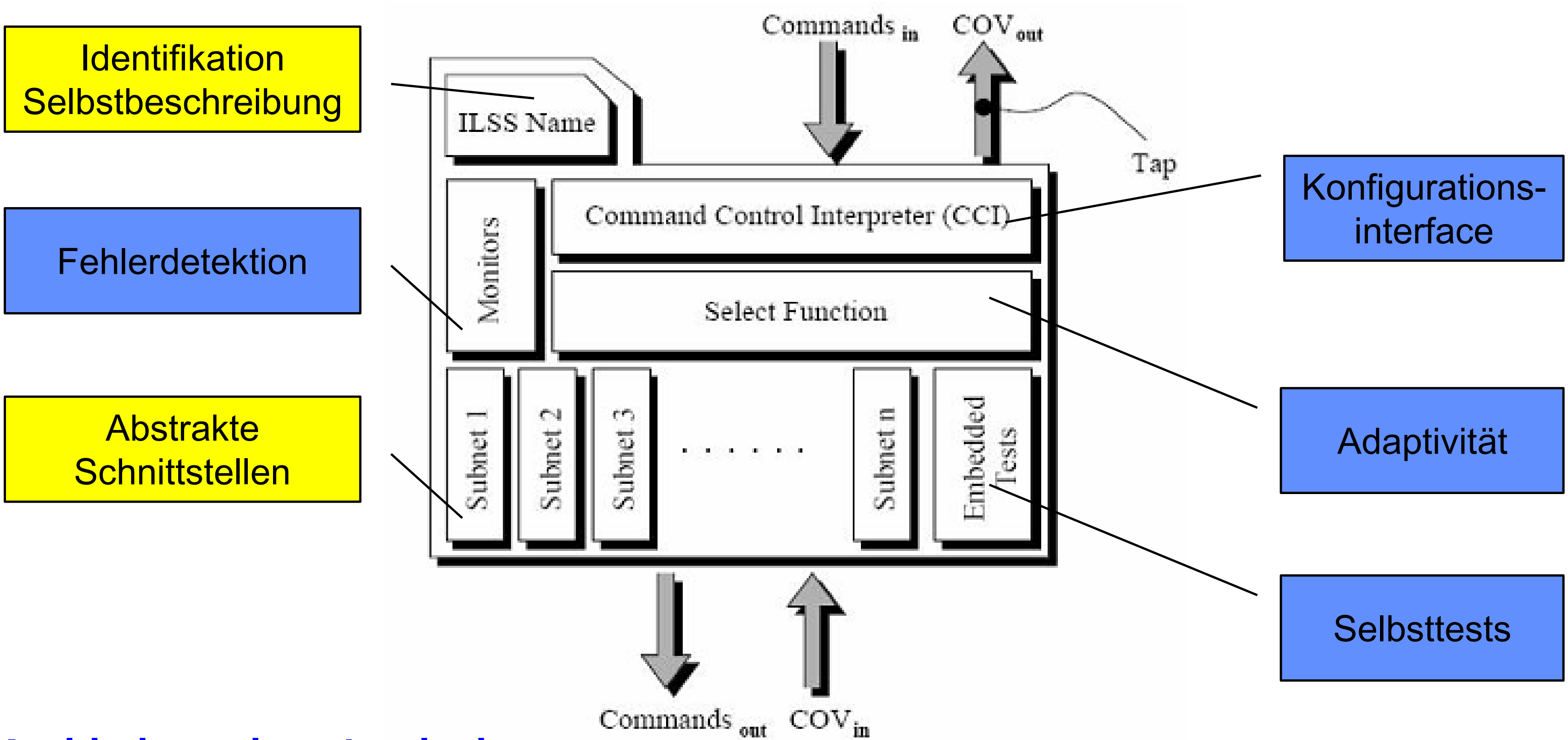
(a) Aufteilung der Komponenten auf unterschiedliche Baugruppen

(b) Integrierter Sensor mit digitalem Interface

(c) Generelle, integierte Verarbeitungseinheit

(d) Vollständig integrierter Sensor

Funktionale Sicht



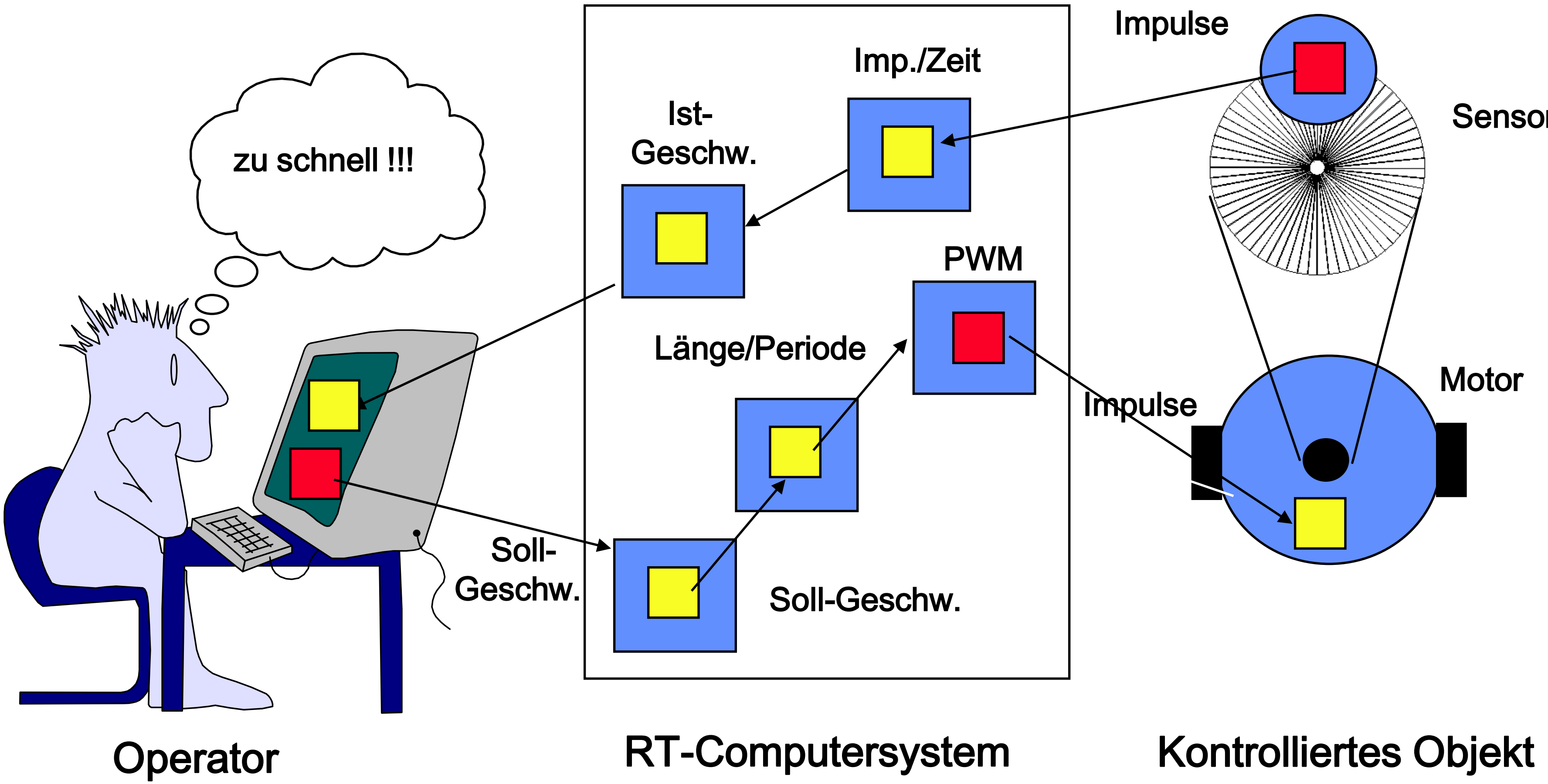
Architektur eines Logischen Sensors nach Henderson

Thomas C. Henderson und Mohamed Dekhil. „Instrumented Sensor System Architecture“. In: *The International Journal of Robotics Research* 17.4 (1998), S. 402–417.

Physische Ereignisse und ihre Repräsentation

RTE: Real Time Entity

RTI: Real Time Image



Instrumentierungsschnittstelle (RWI) und Nachrichtenschnittstelle (MI)

RWI: konkrete low-level Schnittstelle zu einer Komponente, die vom Umfeld festgelegt wird

MI: Interne abstrakte Nachrichtenschnittstelle. Hier wird von physischen Gegebenheiten abstrahiert.

Der Resource-Controller (RC) ist die Schnittstellenkomponente zwischen RWI und MI hat die Rolle eines Wandlers (Transducer*, Transduktor) zwischen der spezifischen Informationsrepräsentation der “Welt” und dem vereinbarten (in Struktur und Semantik) Nachrichtenformat.

Der RC verbirgt die physische Schnittstelle der RW-Komponente von der standardisierten Repräsentation der Information im Rechner.

Der RC kann als eine allgemeine Form eines Gateways interpretiert werden.

* Transducer (Webster): A device that receives energy from one system, and retransmits it, often in a different form, to another.

Vergleich RWI und MI

Charakteristik	RWI	MI
Informationsdarstellung	speziell	standard
Kopplung	eng	lose(r)
Codierung	analog/digital	digital
Zeitbasis	kontinuierlich (dense)	diskret (sparse)
Responsivität	eng	lose(r)
(Netz-)Topologie	1-zu-1	Multicast (n-zu-n)
Entwurfsfreiheit	begrenzt	frei

Beispiele für standardisierte MIs:

- **SAE J 1587**: Message Specification for heavy duty vehicle applications
- **MAP MMS**: Manufacturing Automation Protocol
  Manufacturing Message Specification
- **CanOpen**: Can Application Layer (low level)
- **IEEE 1451:** Smart Transducer Schnittstelle(n)
- **ROS**

Aufbau einer standardisierten ROS Nachricht

```
Header header
float32 angle_min           # start angle of the scan [rad]
float32 angle_max           # end angle of the scan [rad]
float32 angle_increment     # angular distance between measurements [rad]
float32 scan_time           # time between scans [seconds]
float32 range_min           # minimum range value [m]
float32 range_max           # maximum range value [m]
float32[] ranges            # range data [m]
```

Inhalt der laser_msg.msg Datei einer ROS Installation

IEEE 1451: Ein Standard für Intelligente Sensoren und Aktoren

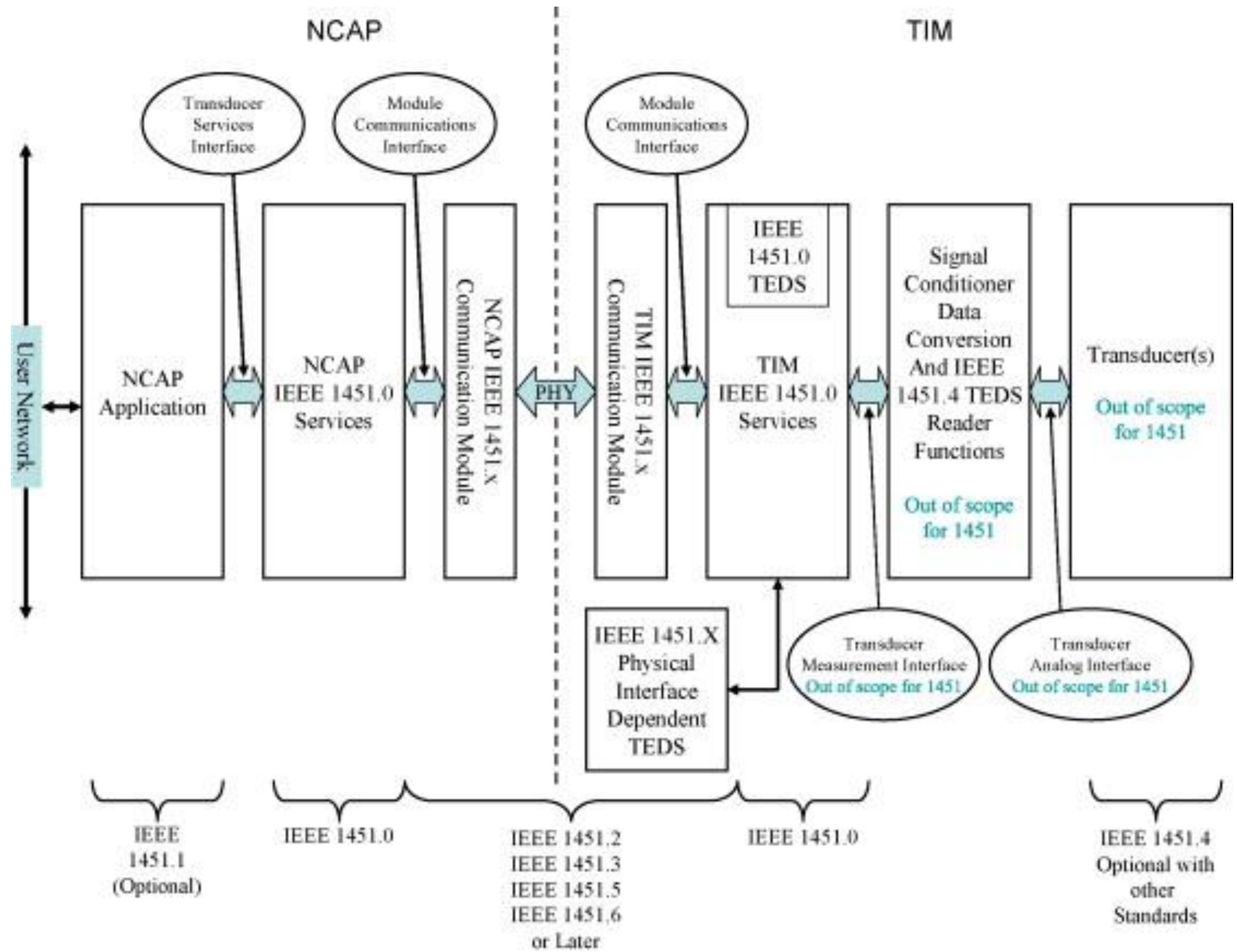
Smart Transducers (ST) stellen Funktionen zur Verfügung, die eine einfache und kontengünstige Erweiterung von Anwendungen ermöglichen. Plug and Play!

Elektronisches Datenblatt
Selbst-Identifikation
Intelligente (und autonome) Kalibrierung, Diagnose und Adaption
Digitale Schnittstelle
Kommunikation

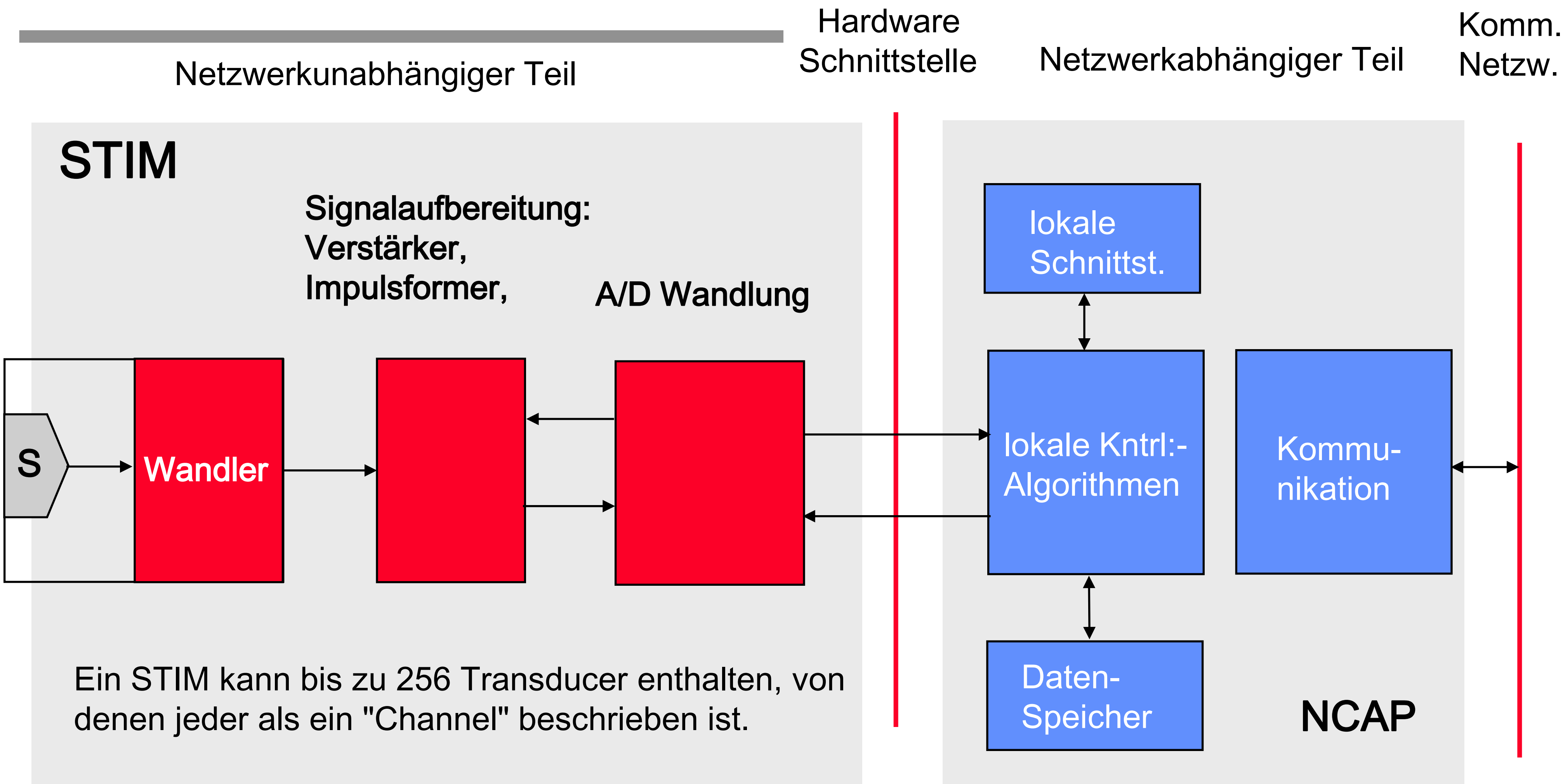
Eigenschaften können "in situ" festgestellt und geändert werden:
Kalibrierung, Korrekturfaktoren, Ort, Typ, Operationsschranken.

In einem dezentralisierten System sind Sensoren nutzlos, wenn nicht:
- ihre korrekte Funktion festgestellt werden kann,
- sie nach Typ und Ort identifiziert werden können und
- ihre Betriebsumstände verifiziert werden können, d.h. sie operieren unter den vom Hersteller angegebenen Bedingungen wie Signalbereich und Umgebungsbedingungen.

Komponenten des IEEE 1451 Standards



IEEE 1451 Smart Transducer Model



1451.2 Smart Transducer Interface Module (STIM)
beschrieben durch: TEDS (Transducer Electronic Data Sheet)

NCAP (Network Capable Processor)

Übersicht TEDS

Meta-TEDS	**One per STIM:** Contains the overall description of the TEDS data structure, worst case STIM timing parameters, and channel grouping information.
Channel TEDS	**One per STIM channel:** Contains upper/lower range limits, physical units, warm up time, presence of self-test, uncertainty, data model, calibration model, and triggering parameters.
Calibration TEDS	**One per STIM channel:** Contains the last calibration date, calibration interval and all the calibration parameters supporting the multi-segment model.
Application specific TEDS	**Multiple per STIM:** For application specific use.
Extension TEDS	**Multiple per STIM:** Used to implement future and industry extensions to P1451.2.

Beispiel: Beschreibung eines Drucksensors

Stan P. Woods, Janusz Bryzek,
Steven Chen, Jeff Cranmer,
Edwin Vivian El-Kareh, Mike Geipel,
Fernando Gen-Kuong, John Houldswort,
Norm LeComte, Kang Lee,
Michael F. Matte, David E. Rasmussen

IEEE-P1451.2 Smart Transducer Interface Module

Meta TEDS				
Field #	Description	Field Length (Bytes)	Field type	Field Contents
	Data structure related information			
1	Meta-TEDS Length	4	U32	48
2	IEEE 1451 Standards Family Working Group Number	1	U8	2
3	TEDS Major Version Number	2	U16	2
4	Future Extensions Key	1	U8	0 (NONE)
5	CHANNEL_ZERO Industry Extensions Key	1	U8	0 (NONE)
6	End Users' Application Specific TEDS Key	1	U8	0
7	Number of Implemented Channels	1	U8	1
8	String Language Code	1	U8	0
9	Bytes per Character	1	U8	1
	Timing related information			
10	Worst Case Channel Data Model Length	1	U8	2
11	Worst Case Channel Data Repetitions	2	U16	1
12	Worst Case Channel Update Time	4	F32	2.00E-05
13	Worst Case Channel Write Setup Time	4	F32	0
14	Worst Case Channel Read Setup Time	4	F32	8.00E-05
15	Input/Output Response Time	4	F32	5.00E-04
16	Calibration TEDS Write Time	4	F32	0
17	Worst Case Data Clock Frequency	4	U32	2.00E+05
18	Worst Case Channel Sampling Period	4	F32	2.00E-04
19	Worst Case Unit Warm Up Time	4	F32	1
	Channel grouping related information			
20	Channel Groupings Data Sub-Block Length	2	U16	0
21	Number of Channel Groupings = G	0	U8	-
22	Group Name Length	0	U8	-
23	Group Name (<= 255)	0	STRING	-
24	Group Type	0	U8	-
25	Number of Group Members = N	0	U8	-
26	Member Channel Numbers List = M(N) (<= 255)	0	array of U8	-
	Data integrity information			
27	Checksum for Meta-TEDS	2	U16	62856

U8, U16, U32 are unsigned integers of length 8, 16 and 32 bits respectively.
F32 is a single precision IEEE floating point number
STRING is an array of character bytes
UNITS is the SI representation

Beispiel: Beschreibung eines Drucksensors

	Data structure related information			
28	Meta-Identification TEDS Length	4	U32	310
	Identification related information			
29	Manufacturer's Identification Length	1	U8	55
30	Manufacturer's Identification (<= 255)	55	STRING	Texas Instruments Incorporated Control Product Division
31	Model Number Length	1	U8	9
32	Model Number (<= 255)	9	STRING	EX3514.XX
33	Revision Code Length	1	U8	2
34	Revision Code	2	STRING	01
35	Serial Number Length	1	U8	5
36	Serial Number (<= 255)	5	STRING	SN-01
37	Date Code Length	1	U8	25
38	Date Code (<= 255)	25	STRING	November 1, 1995, Shift 1
39	Product Description Length	2	U16	205
40	Product Description (<= 65535)	205	STRING	Description: Ratiometric Pressure Transducer Part Number: EX3514.XX Serial Number: SN-01 Pressure Range: 0 To 3000 PSIA Input Voltage: 5 Vdc Output Voltage: 0 To 5 Vdc Temperature Range: -40 To 85° C
	Data integrity information data sub-block			
41	Checksum for Meta-Identification TEDS	2	U16	38702

Beispiel: Beschreibung eines Drucksensors

Channel TEDS				
Field #	Description	Field Length (Bytes)	Field type	Field Contents
	Data structure related information			
42	Channel TEDS Length	4	U32	80
43	Calibration Key	1	U8	1 (FIXED)
44	Industry Extension Key	1	U8	0 (NONE)
	Transducer related information			
45	Lower Range Limit	4	F32	0
46	Upper Range Limit	4	F32	20684190
47	Physical Units	10	UNITS	Pa (0,128,128,126,130, 124,128,128,128,128)
48	Unit Type Key	1	U8	0 (SENSOR)
49	Unit Warm Up Time	4	F32	1
50	Self Test Key	1	U8	0 (NONE)
51	Uncertainty	4	F32	206842
	Data converter related information			
52	Channel Data Model	1	U8	0 (N BYTE)
53	Channel Data Model Length	1	U8	2
54	Channel Model Significant Bits	2	U16	12
55	Channel Data Repetitions	2	U16	1
56	Series Increment	4	F32	0
57	Series Units	10	UNITS	0
58	Channel Update Time	4	F32	2.00E-05
59	Channel Write Setup Time	4	F32	0
60	Channel Read Setup Time	4	F32	8.00E-05
61	Data Clock Frequency	4	U32	2.00E+05
62	Channel Sampling Period	4	F32	2.00E-04
63	Timing Correction	4	F32	0
64	Trigger Accuracy	4	F32	5.00E-06
	Data integrity information			
65	Checksum for Channel TEDS	2	U16	59968
	Data structure related information			
66	Channel Identification TEDS Length	4	U32	8
	Identification related information			
67	Manufacturer's Identification Length	1	U8	0
68	Manufacturer's Identification (<= 255)	0	STRING	-
69	Model Number Length	1	U8	0
70	Model Number (<= 255)	0	STRING	-
71	Revision Code Length	1	U8	0
72	Revision Code (<= 255)	0	STRING	-
73	Serial Number Length	1	U8	0
74	Serial Number (<= 255)	0	STRING	-
75	Channel Description Length	2	U16	0
76	Channel Description (<= 65535)	0	STRING	-
	Data Integrity information			
77	Checksum for Channel Identification TEDS	2	U16	65527

Beispiel: Beschreibung eines Drucksensors

Calibration TEDS				
Field #	Description	Field Length (Bytes)	Field type	Field Contents
	Data structure related information			
78	Calibration TEDS Length	4	U32	99
	Calibration related information			
79	Last Calibration Date-Time	4	U32	0
80	Calibration Interval	4	U32	0
81	Number of Correction Input Channels = n	1	U8	1
82	Correction Input Channel List	1	U8	1
83	Correction Input Channel-Key List	1	U8	0
84	Channel Degree List = D(k)	1	U8	1
85	Number of Segments List = N_k	1	U8	5
86	Segment Boundary Values Table (Pa)	24	F32	0
	(segment 1 high boundary)		F32	4136838
	(segment 2 high boundary)		F32	8273676
	(segment 3 high boundary)		F32	12410514
	(segment 4 high boundary)		F32	16547352
	(segment 5 high boundary)		F32	20684190
87	Segment Offset Values Table (Pa)	20		
	(segment 1 offset)		F32	5051
	(segment 2 offset)		F32	5051
	(segment 3 offset)		F32	5051
	(segment 4 offset)		F32	5051
	(segment 5 offset)		F32	5051
88	Multinomial Coefficients	40		
	A_{00} (Pa)		F32	-126372
	A_{01} (Pa/count)		F32	5244
	A_{10}		F32	-44141
	A_{11}		F32	5144
	A_{20}		F32	111220
	A_{21}		F32	5049
	A_{30}		F32	331826
	A_{31}		F32	4959
	A_{40}		F32	610811
	A_{41}		F32	4874
	Data integrity information			
89	Checksum for Calibration TEDS	2	U16	57092

Physikalische Basiseinheiten: http://de.wikipedia.org/wiki/Internationales_Einheitensystem

Quantity	Unit	Symbol
Länge	meter	m
Masse	Kilogramm	kg
Zeit	Sekunden	s
Elektr. Strom	Ampère	A
Thermodynamische Temperatur	Kelvin	K
chem. Masseeinheit	Mol	mol
Lichtintensität	Candela	cd

ISO 31-0:1992(E), “General Introduction to ISO 31—General Principles Concerning Quantities, Units and Symbols,” International Organization for Standardization, Geneva, Switzerland, 1974.

Derived quantity	Special name	Special symbol	Expression in terms of other SI units	Expression in terms of SI Base units
plane angle	radian	rad		$m\ m^{-1}=1$
solid angle	steradian	sr		$m^2\ m^{-2}=1$
frequency	hertz	Hz		s^{-1}
area (square meter)				m^2
volume (cubic meter)				m^3
acceleration (meter per second squared)				m/s^2
wave number (reciprocal meter)				m^{-1}
mass density(density) (kilogram per cubic meter)				kg/m^3
specific volume (cubic meter per kilogram)				m^3/kg
current density (ampere per square meter)				A/m^2
magnetic field strength (ampere per meter)				A/m
amount-of-substance concentration (mole per cubic meter)				Mol/m^3
luminance (candela per square meter)				cd/m^2
force	newton	N		$m\ kg\ s^{-2}$
pressure, stress	pascal	Pa	N/m^2	$m^{-1}kg\ s^{-2}$
energy, work, quantity of heat	joule	J	N m	$M^2\ kg\ s^{-2}$
power, radiant flux	watt	W	J/s	$m^2\ kg\ s^{-3}$
electric charge, quantity of electricity	coulomb	C		s A
electric potential, potential difference, electromotive force	volt	V	W/A	$m^2kg\ s^{-3}A^{-1}$
capacitance	farad	F	C/V	$m^{-2}\ kg^{-1}\ S^4\ A^2$
electric resistance	ohm	Ω	V/A	$m^2\ kg\ s^{-3}\ A^{-2}$
electric conductance	siemens	S	A/V	$m^{-2}\ kg^{-1}\ s^3\ A^2$
magnetic flux	weber	Wb	V s	$m^2\ kg\ s^{-2}\ A^{-1}$
magnetic flux density	tesla	T	Wb/m^2	$kg\ s^{-2}\ A^{-1}$
inductance	henry	H	Wb/A	$m^2\ kg\ s^{-2}A^{-2}$
Celsius temperature	degree Celsius	°C		K
luminous flux	lumen	lm		cd sr
illuminance	lux	lx	lm/m^2	$m^{-2}\ cd\ sr$

Normierte Darstellung physikalischer Parameter in 1451.2

Field #	Description	# bytes
1	ENUMERATION 0: Unit is described by the product of SI base units raised to the powers recorded in fields 2 through 10.	1
	1: Unit is U/U, where U is described by the product SI base units raised to the powers recorded in fields 2 through 10.	
	2: Unit is $\log_e(U)$, where U is described by the product of SI base units raised to the powers recorded in fields 2 through 10.	
	3: Unit is $\log_e(U/U)$, where U is described by the product of SI base units raised to the powers recorded in fields 2 through 10.	
	4: The associated quantity is digital data (e.g. a bit vector) and has no unit. Fields 2-10 shall be set to 128.	
	5-255: Reserved	
2	(2 * <exponent of radians>) + 128	1
3	(2 * <exponent of steradians>) + 128	1
4	(2 * <exponent of meters>) + 128	1
5	(2 * <exponent of kilograms>) + 128	1
6	(2 * <exponent of seconds>) + 128	1
7	(2 * <exponent of amperes>) + 128	1
8	(2 * <exponent of kelvins>) + 128	1
9	(2 * <exponent of moles>) + 128	1
10	(2 * <exponent of candelas>) + 128	1

SI: Le Système International d'Unités.

Beispiele:

Nur die Dimension, nicht der Wert wird codiert!

Länge in Metern

	Enum	rad	sr	m	kg	s	A	K	mol	cd
exponent	0	0	0	1	0	0	0	0	0	0
decimal		128	128	130	128	128	128	128	128	128

Fläche in m^2

	Enum	rad	sr	m	kg	s	A	K	mol	cd
exponent	0	0	0	2	0	0	0	0	0	0
decimal		128	128	132	128	128	128	128	128	128

Druck in pascal = m^{-1} kg s^{-2}

	Enum	rad	sr	m	kg	s	A	K	mol	cd
exponent	0	0	0	-1	1	-2	0	0	0	0
decimal		128	128	126	130	124	128	128	128	128

Widerstand in Ω = m^2 kg s^{-3} A^{-2}

	Enum	rad	sr	m	kg	s	A	K	mol	cd
exponent	0	0	0	2	1	-3	-2	0	0	0
decimal		128	128	132	130	122	124	128	128	128

Noise Spectral Density : volts per root Hertz ($V/\sqrt{hz}$ = m^2 kg $s^{-5/2}$ A^{-1})

	Enum	rad	sr	m	kg	s	A	K	mol	cd
exponent	0	0	0	2	1	-5/2	-1	0	0	0
decimal		128	128	132	130	123	126	128	128	128

Power Quantity - Bel (log10 W/W) W = m^2 kg s^{-3}

	Enum	rad	sr	m	kg	s	A	K	mol	cd
exponent	3	0	0	2	1	-3	0	0	0	0
decimal		128	128	132	130	122	128	128	128	128

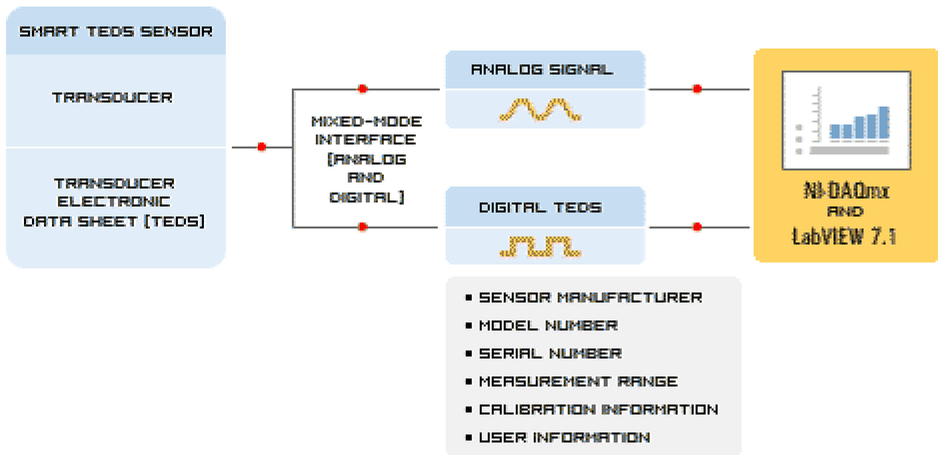
Beispiele:

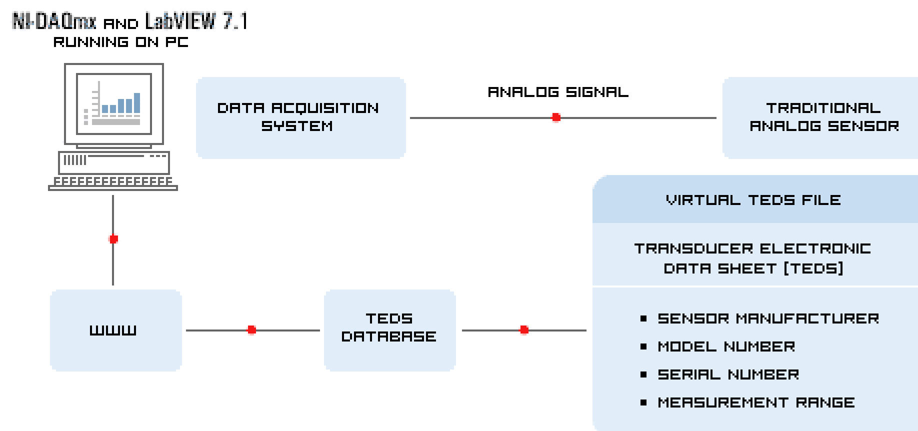
Switch Positions

	Enum	rad	sr	m	kg	s	A	K	mol	cd
exponent	4	0	0	0	0	0	0	0	0	0
decimal		128	128	128	128	128	128	128	128	128

Lee H. Eccles (Boeing Commercial Airplane Company): Physical Units Representation in IEEE 1451.2

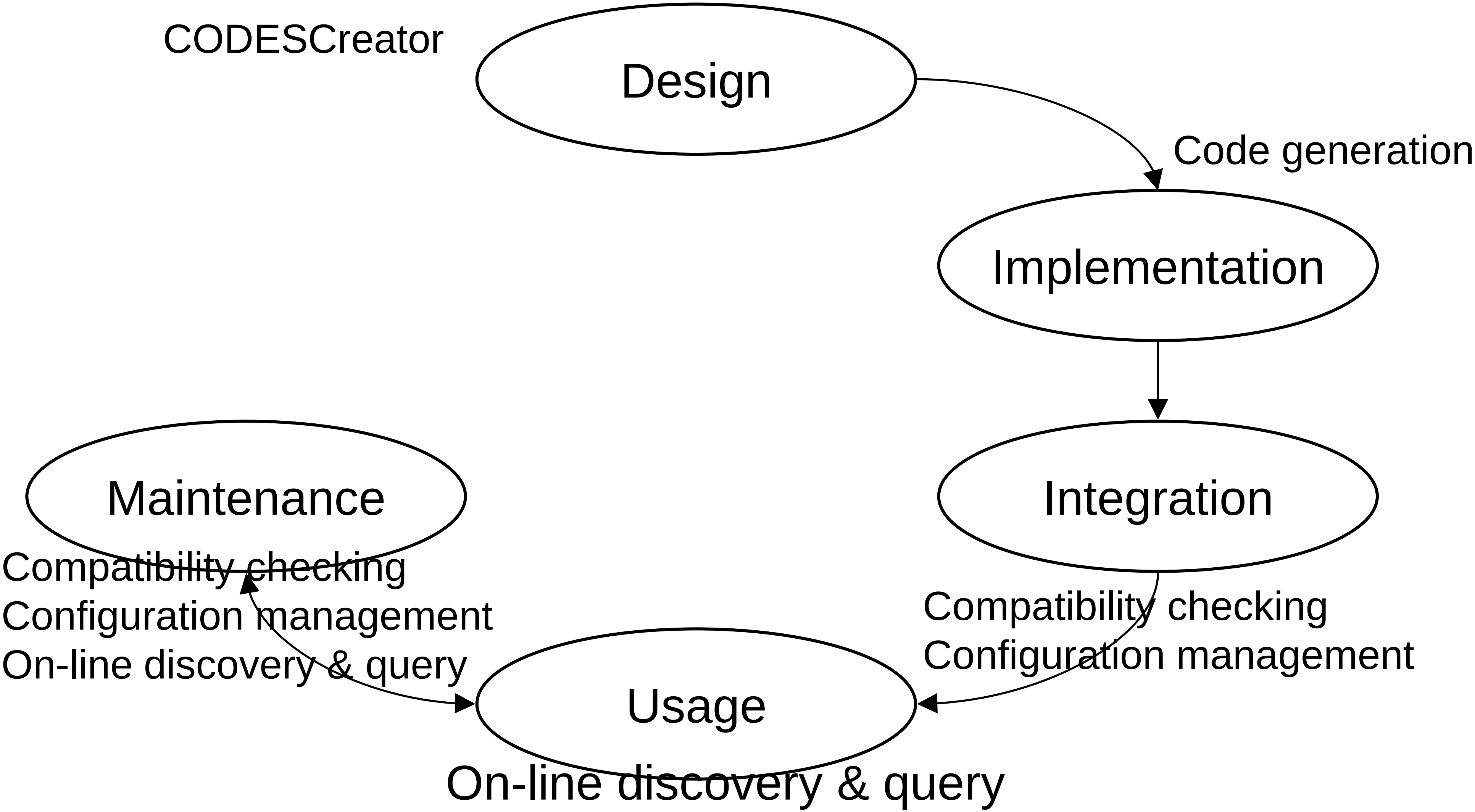
Anwendungsvariante 1: National Instruments



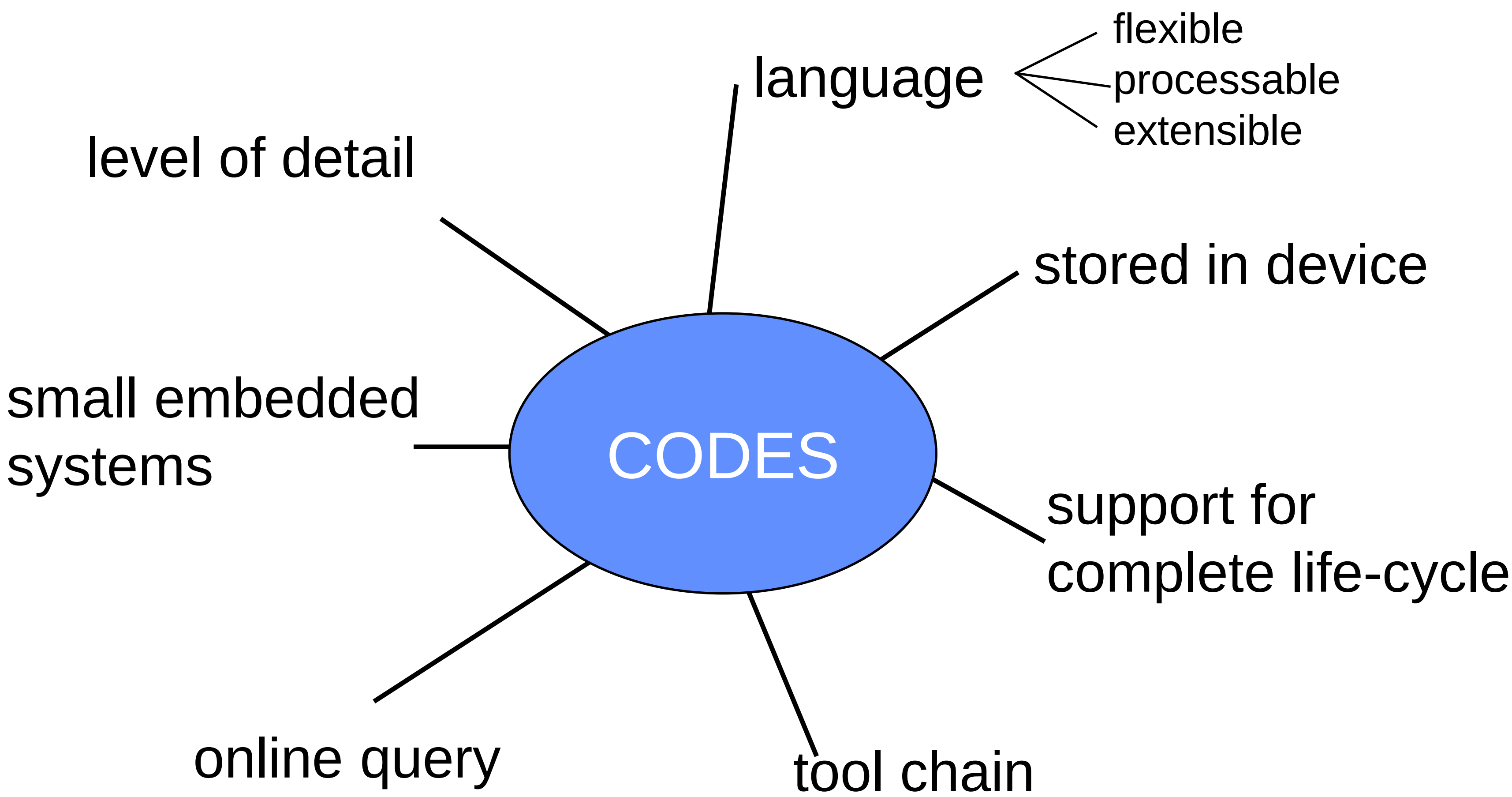


Source: Webseite National Instruments

Anwendungsvariante 2: CODES - COsmic embedded DEvice Specifications



CODES – Overview

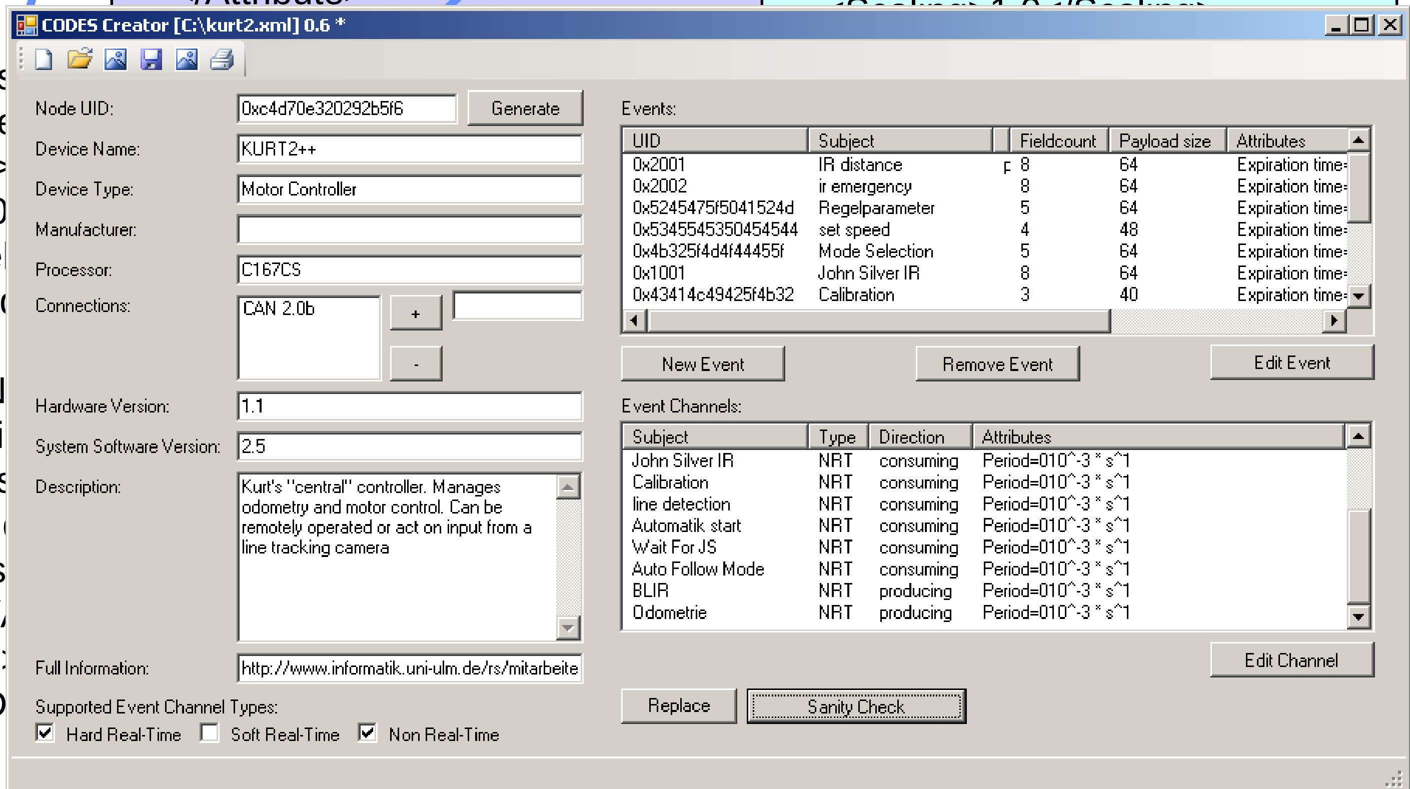


CODES – Details

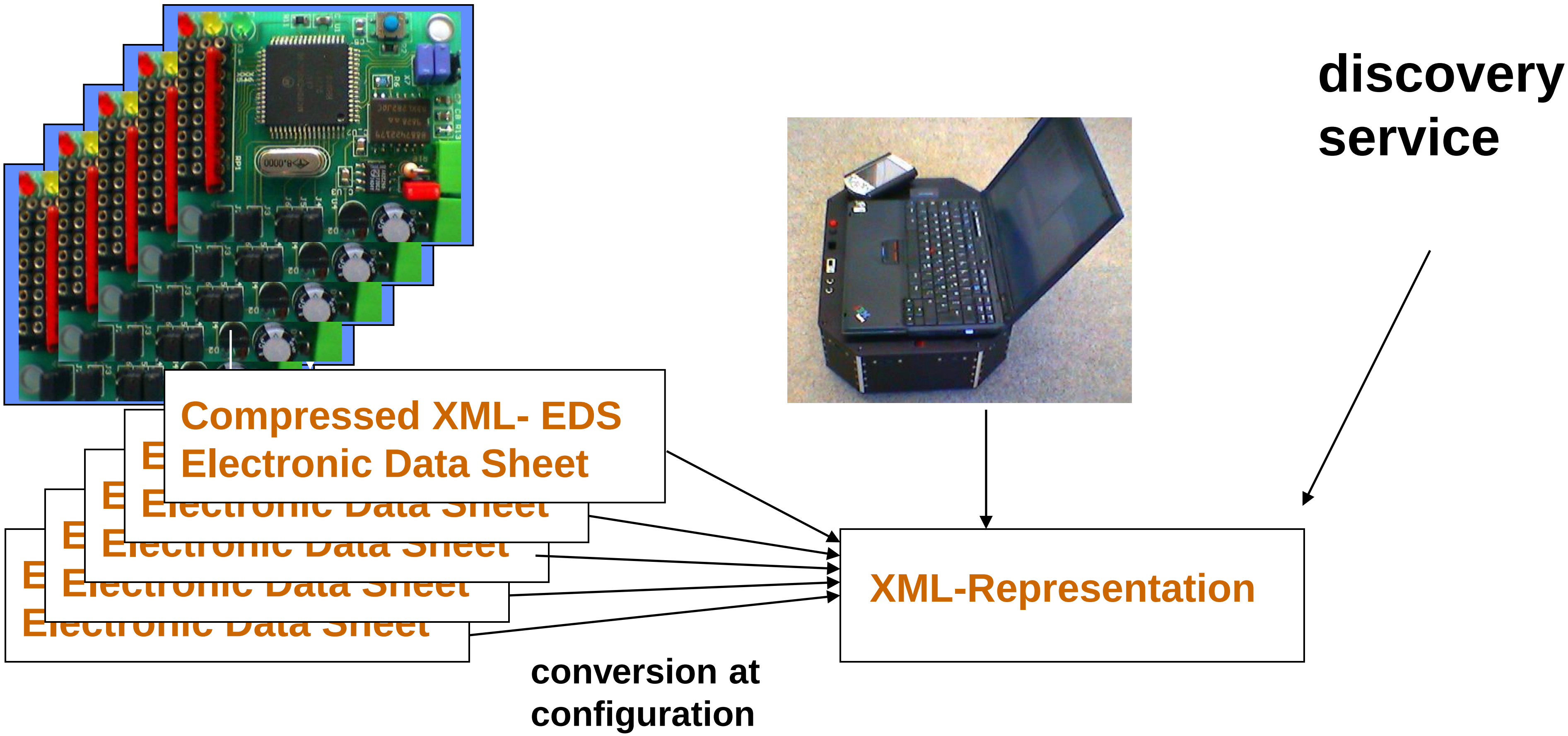
```
<CODES>
  <GeneralInformation>
    <NodeUID>0xC4D70E
    <DeviceName>IR Dista
  </GeneralInformation
  <EventDefinitions>
    <Event />
  </EventDefinitions
  <EventChannelDe
    <EventChannel>
      <SubjectUID>0
      <EventChannel
      <Direction>proc
      <Attributes>
        <Attribute><N
            <Dimensi
            <Seconds
            <Magnitu
            </Dimens
        </Attribute></
    </EventChannel
  </EventChannelD
</CODES>
```

```
<Event>
  <Subject />
  <Attributes>
    <Attribute>
      <Name>ExpirationTime</Name>
    </Attribute>
```

```
<Name>Distance</Name>
<DataType>u_int_16_t</DataType>
<Dimension>
  <SIUnit>
    <Meters>1.0</Meters>
    <Magnitude>-3.0</Magnitude>
```



Anwendungsvarianten 2: CODES



Example:

static device information

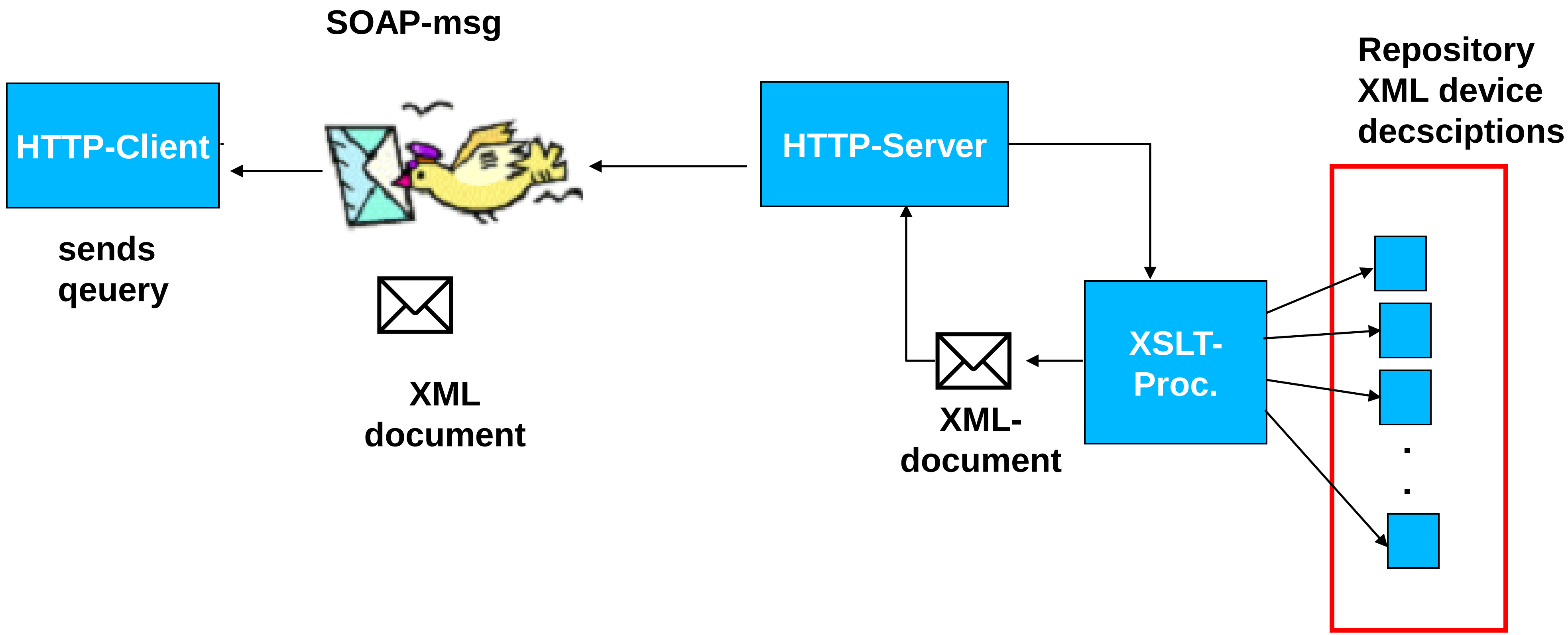
```
<?xml version="1.0" encoding="ISO-8859-1"?>

<DeviceInformation xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:noNamespaceSchemaLocation="sensor.xsd">

<static_device_info>
<DeviceName>Accerlation Sensor</DeviceName>
<DeviceType>TYNI_ADXL_UNIULM</DeviceType>
<ManufacturerName>University of Ulm</ManufacturerName>
<Processor>68HC908AZ60</Processor>

<operat_con>
<operational_connection>CAN 2.0b</operational_connection>
</operat_con>
<operat_con>
<operational_connection>Serial Line</operational_connection>
</operat_con>

<HardwareVersion>1.01</HardwareVersion>
<SystemSoftwareVersion>2.0</SystemSoftwareVersion>

<Description>Text. Great.</Description>
<NodeUID>0x1234567812345678LL</NodeUID>

<FullDataSheet>http://myDataSheet</FullDataSheet>
<FullConfigurationInfo>http://myConfigurationInfo</FullConfigurationInfo>
<DiagnosticInfo>http://myDiagnosticInfo</DiagnosticInfo>

<supported_channel_types>
<HRT>false</HRT>
<SRT>true</SRT>
<NRT>false</NRT>
</supported_channel_types>
...
.....
```

Example:

event description

```
<event>
<EventName>Acceleration 2-axis</EventName>
<Subject>acceleration</Subject>
<SubjectUID>0x0000000000000000BLL</SubjectUID>
<data_structure>
<Name>acceleration x-axis</Name>
<DataType>unsignedByte</DataType>
<pe>
        <!--<Unit>G</Unit>-->
        <SIUnit>
                <Enumeration>128</Enumeration>
                <Radians>128</Radians>
                <Steradians>128</Steradians>
                <Meters>130</Meters>
                <Kilograms>128</Kilograms>
                <Seconds>124</Seconds>
                <Amperes>128</Amperes>
                <Kelvins>128</Kelvins>
                <Moles>128</Moles>
                <Candelas>128</Candelas>
        </SIUnit>
        <Value>0</Value>
</pe>
</data_structure>
<data_structure>
..
..
</data_structure>
..
..
</event>
```

Anwendungsvariante 2: CODES



Wesentliche Punkte:

Sensoren und Aktoren sind äußerst diversitär was ihre spezifischen Eigenschaften, die Schnittstelle und die Art ihrer Informationsdarstellung betrifft.

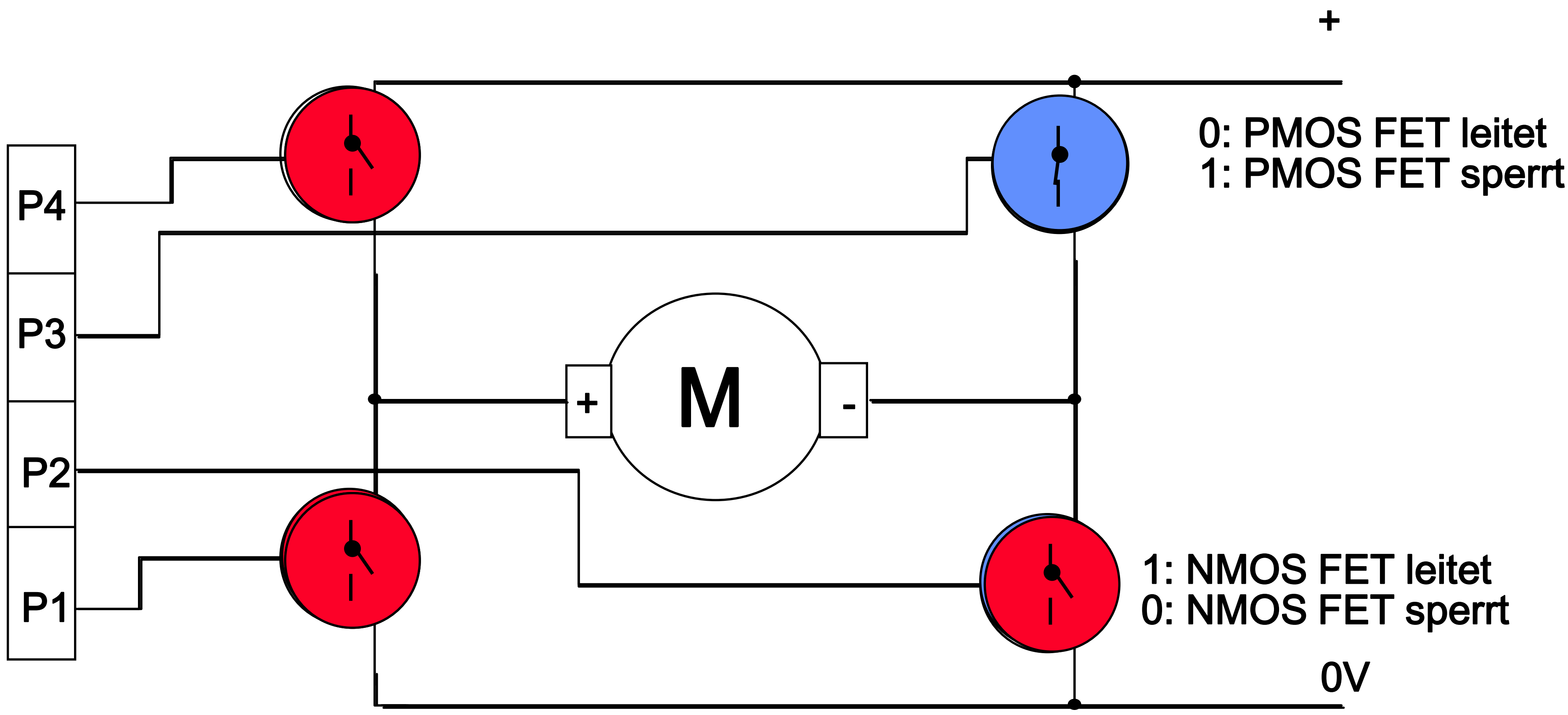
Eine informationsverarbeitende Komponente ermöglicht eine anwendungsangepasste Aufbereitung, standardisierte (Netzwerk-) Schnittstelle und Informationsdarstellung.

Eine Beschreibung der Sensoren und Aktoren ermöglicht eine dynamische Konfiguration und Erweiterung eines Sensor/Aktor-Systems.

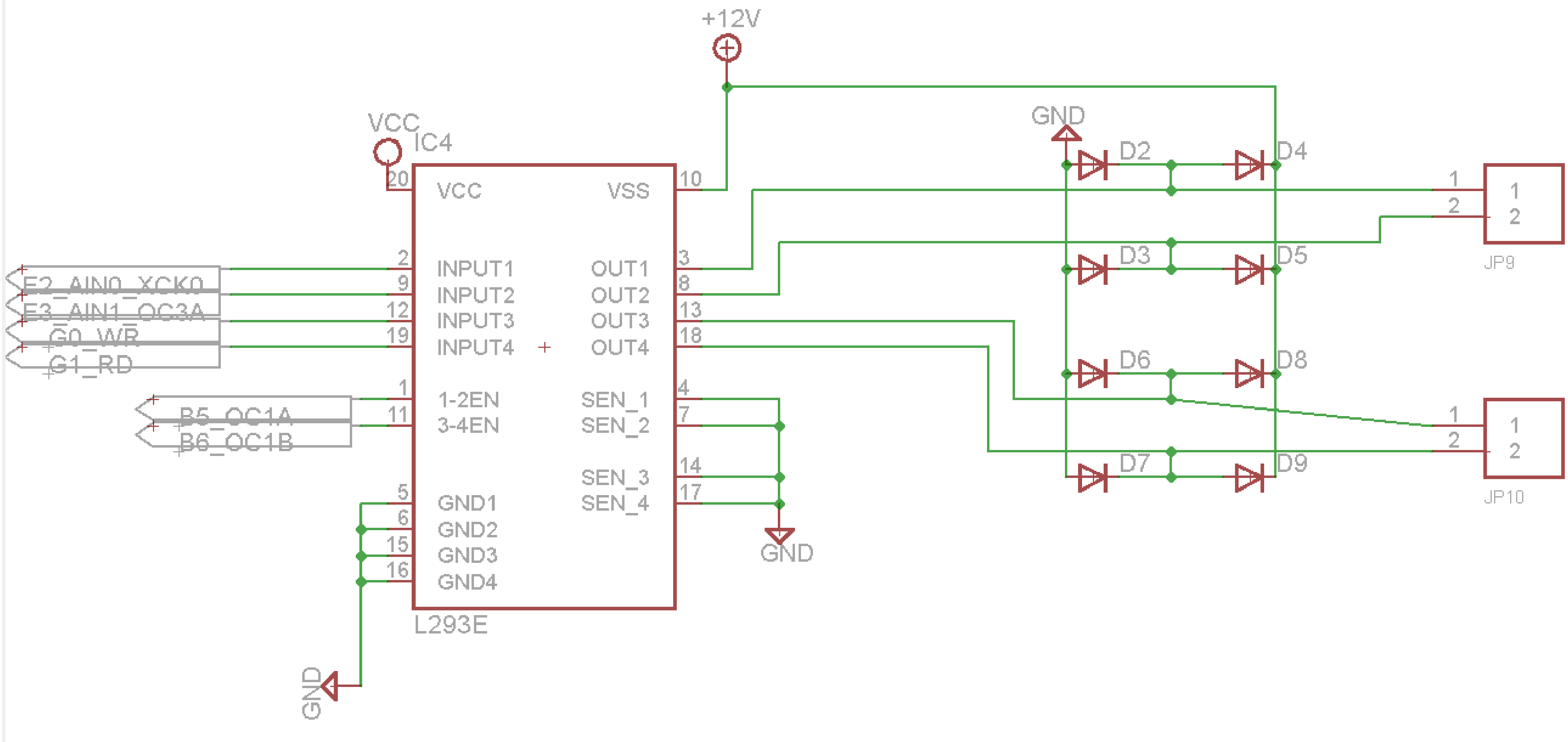
3. Aufgabenblatt

Ansteuerung des Motors

Motorsteuerung mit PWM-Kanälen



Beschaltung des Robbies



Timerkonfiguration

OC1A, OC1B = Timer 1 (10 bit Timer)
Phase Correct PWM !

- **Richtungspins als Ausgang definieren**
- **PWM Pins als Ausgang konfigurieren und “0” setzen**
- **Phase Correct PWM setzen**
- **Reaktion der Pins (B5_OC1A, B6_OC1B) konfigurieren**
- **Prescaler setzen**

INITIALBUTTON im Code einfügen !