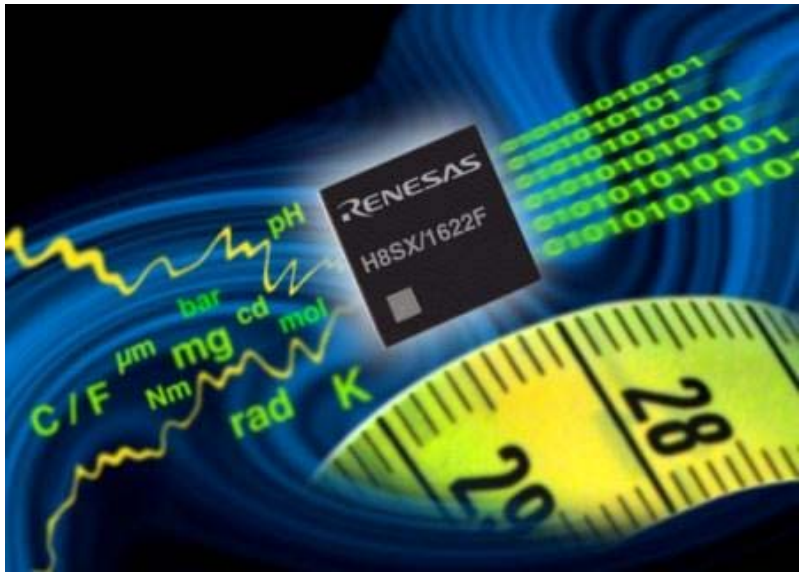
Everywhere you imagine. RENESAS

Design Considerations for Embedded Sensor Solutions in Industrial Applications

August 2008

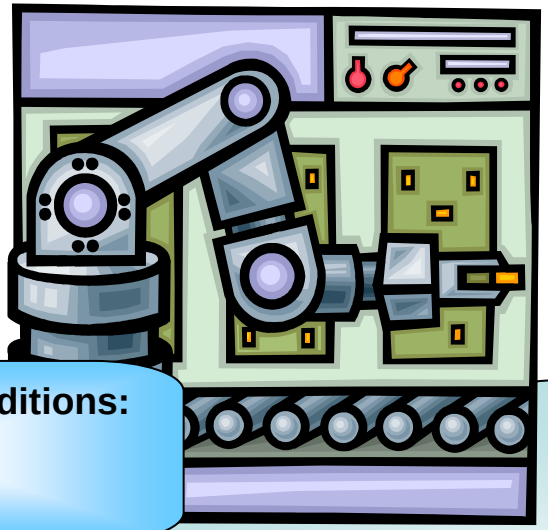


Renesas Technology Europe

02/09/2008

Key Requirements and Use Cases

Industrial Application



Embedded Sensor

Environment Conditions:
- **Temperature**
- **Electrical Noise**
- **Mechanical**

- Robustness
- Reliability
- Safety
- Realtime
- Standardization

Life time
Quality Level
Recovery

Fail-safe
Redundancy

Deterministic

Interoperability

- Measurement
- Intelligence
- Connectivity
- Security
- Tiny
- Low Power
- (Actuator Functio

Accuracy
Realtime
Range

Data Storage
Pre-processing
Adaptivity

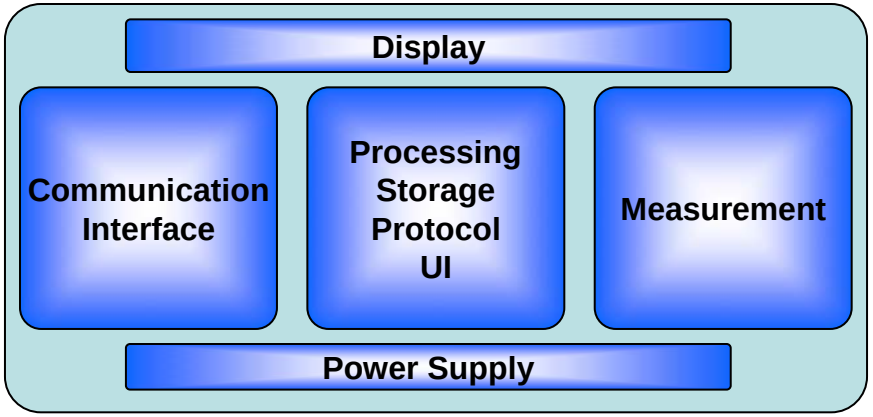
Response
Event
Setup

Encryption
Decryption
Key Setup

Battery
Energy Efficient

Alarm
Display
Control

System Concept



- **Separate measurement function from other intelligence to simpliy certification process?**
- **Separate communication interface from other intelligence for modularity?**
- **Or integrate everything to achieve small form factor?**
- **Display options:**
  - Display has built-in display driver
  - MCU has built-in display driver
  - LCD SW driver, TFT Direct Drive
- **Non volatile memory for data storage (data flash) and adaptivity (firmware update)**
- **Power supply**
  - Uncritical: Line powered or laptop size battery
  - Medium: re-chargeable batteries , medium lifetime
  - High: 10~20 years of lifetime (Calculation of runtime, wake-up time, sleep time needed)
- **Increase reliability and safety by**
  - self-test SW or HW (according to e.g. IEC60730)
  - redundant MCU concept (watchdog MCU, asymmetric/symmetric dualcore, etc.)
- **Availability of development tools, application notes and sample code (as close as possible to real application) to improve time-to-market**
- **Mechanical aspects (Industrial housing, etc.)**

MCU Selection Criteria for Industrial Sensor Applications

- ✓ **Low Power Features**
  - ✓ Stop mode (wake up by external event)
  - ✓ Low voltage operation (1,8V)
  - ✓ Subclock
  - ✓ Real Time Clock
- ✓ **Reliability Features**
  - ✓ Power-On-Reset
  - ✓ Low Voltage Detection (2 steps)
  - ✓ On Chip Oscillator (low speed / high speed)
  - ✓ Oscillator stop detection
  - ✓ Watchdog
  - ✓ Protected Registers
- ✓ **Memory features**
  - ✓ Scalable memory variants
  - ✓ Flash memory (BGO programming mode, 20 years data retention)
  - ✓ Data Flash
  - ✓ Protection
- ✓ **Sensor Features**
  - ✓ ADC, External Interrupts, Event Counter, Input Capture, Wake-Up
  - ✓ AD trigger by any external or interrupt source
- ✓ **Actor Features**
  - ✓ DAC, PWM, Output Compare
- ✓ **Performace**
  - ✓ Enough for data pre-processing, protocol handling, user interface
  - ✓ DMA or DTC (Data Transfer Controller)
- ✓ **Supplier**
  - ✓ Qualified for Industrial / Automotive applications
  - ✓ Excellent quality record
  - ✓ Long term supply guarantee
  - ✓ toolchain
  - ✓ support

MCU proposals for intelligent sensors

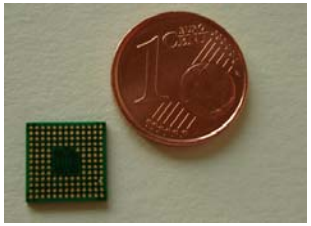
20pin SSOP
4.4 x 6.5x 1.45mm
0.65mm pitch

28pin QFN
5 x 5 x 0.75mm
0.5mm pitch

64pin LGA
6 x 6 x 1.05 mm
0.65mm pitch

Type	R8C/18 R8C/19 R8C/1A R8C/1B	R8C/24 R8C/25 R8C/2A R8C/2B	H8/38602RF	H8/38076RF
Package	20pin SSOP 4,4mmx6,5mm 0,65mm pitch or 28pin QFN 5x5x0,75mm 0,5mm pitch	64pin LGA 6mmx6mm 0,66mm pitch	32pin QFN 5mmx6mm 0,5mm pitch	TLP85 7mmx7mm 0,65mm pitch
Performance	16bit CPU 20MHz	16 bit CPU 40MHz	16 bit CPU 10MHz	16bit CPU 10MHz
Low Power Modes	Stop Mode: 0,8µA Low Speed-OCO mode: 110uA	Stop mode: 0,8µA Low Speed-OCO mode: 110uA	Watch mode: 0,45µA/1.8V Subactive: 6µA/2V/32kHz Active: 1mA/2V/2MHz	Watch mode: 0,5µA/1.8V Subactive: 5µA/1.8V/32kHz Active: 1mA/1.8V/2MHz
Special Feature Highlights	I2C, SSI, UART, ADC, DAC Easy migration path to M16C,M32C,R32C	CAN, LIN, DTC 40MHz OCO Easy migration path to M16C,M32C,R32C	2,4kbps UART in sub-active mode (38,4kHz) ADC @ 32kHz Fast wake-up IrDA	Low power communication Low power measurement Fast wake-up IrDa LCD driver and charge pump 14bit ADC (H838086)
Starter Kit	RSKR8C1B	RSKR8C23, 25, 27 RSKR8C2D, 2F	RSKH836079 RSKH838099	RSKH836079 RSKH838099
Example Sensor Application	Dirt Sensors for White Goods		Gas Sensors Smoke Sensors	Glucose Meters Electricity Meters Gas Meters Water Meters

MCU proposals for intelligent sensors



Type	H8SX/1622	SH7083	SH7125
Package	TLP145 9mmx9mm 0,65mm pitch	112pin BGA 10mmx10mm 0,8mm pitch	QFN52 7,2x7,2mm, 0,4mm pitch or QFN64 8mmx8mm, 0,4mm pitch
Performance	32bit CPU 50MHz Onchip MUL/DIV	32 bit RISC 104MIPS@80MHz	32 bit RISC FPU 200MFLOPS peak performance Double/Single precision Sinus: 680ns double precision
Low Power Modes	6 low power modes HW standby: 3uA Deep standby: 4uA Deep standby (keep RAM): 19uA	Deep standby: 5uA SW standby: 10mA	SW standby: 5mA
Special Feature Highlights	16bit ADC (6 ch) Power cut off Smart Card IF	Most powerful MCU in smallest package	Easy migration path up to 480DMIPS/4.2GFlops MPUs (e.g. SH7722 for multimedia applications)
Starter Kit	RSKH8SX1622	RSKSH7086 RSKSH7286	RSKSH7124
Example Sensor Application	Humidity Sensor Thermo Sensor	Cameras Motor Drives Compact Health Goods	Cameras Inverters Compact Health Goods

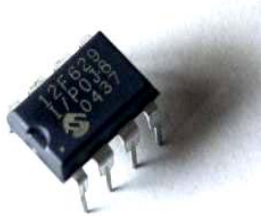
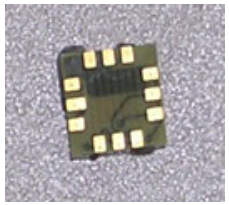
How to combine MCU and sensor

✓ Application Notes

- ✓ Connecting a **pyroelectric infrared sensor** to H8/300 Tiny series (rej06b0121.pdf)
- ✓ Connecting a semiconductor type accleeration sensor to H8/300 Tiny series (rej06b0129.pdf)
- ✓ Connecting a **pressure sensor** to H8/300 Tiny series (rej06b0130.pdf)
- ✓ Connecting **gas sensor** for detecting air contaminants to H8/300 SLP (rej06b0194.pdf)
- ✓ Connecting **angular velocity sensor** to H8/300 Tiny series (rej06b0221.pdf)
- ✓ Connecting an **acceleration sensor** to H8/300 SLP (rej06b0290.pdf)
- ✓ Connecting a **pressure sensor** to H8/300 SLP (rej06b0291.pdf)
- ✓ **Sensor connection** with low supply current using comparator and A/D converter (rej06b0644_h8300hslpap.pdf)
- ✓ **Lux meter** for M16C/26A (rej05b0811_m16cap.pdf)
- ✓ **Sensor's output impedance** under A-D conversion for M16C/62 (rej05b0278_m16cap.pdf)
- ✓ **Detailed usage guidelines of ADC** for H8/300 SLP (res0007_h8300slp.pdf)
- ✓ **Ultrasonic range finder** using H8/300 SLP (res0009_h8300slp.pdf)
- ✓ Direction finder using **hall effect sensor** with H8/300 SLP (res0010_h8300slp.pdf)
- ✓ **Safety Software** according to IEC60730 Class B (app22330.pdf)

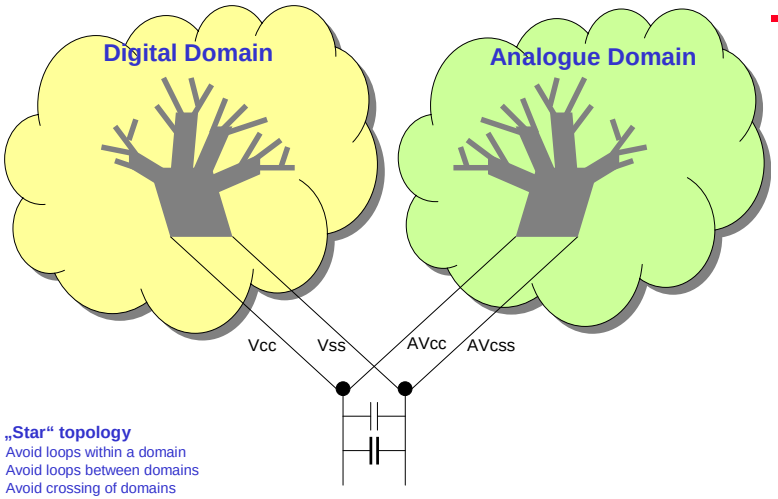
RENESAS R8C Flash + RENESAS H8S + RENESAS H8SX + RENESAS SH Tiny

Rich Selection of Small Sensors

Silicon Micro Sensor	Compression sensor	Gyro Sensor (Angle Sensor)	Temperature Sensor	Acceleration Sensor
				

ADC Considerations: Traditional Approaches

Layout Considerations



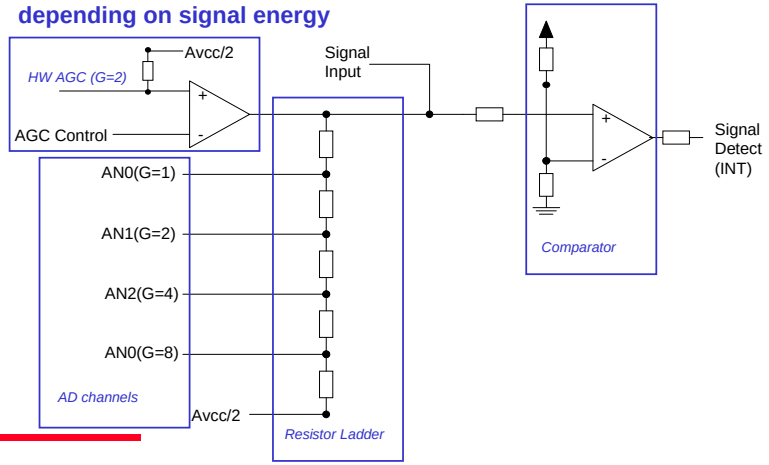
Use „Star“ topology
- Avoid loops within a domain
- Avoid loops between domains
- Avoid crossing of domains

Special care for all signals >0,5MHz (clock, SPI, etc.)

Follow guidelines for all unused pins (connect to GND or unconnected output to „Low“)

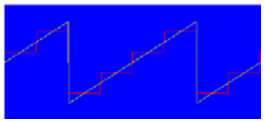
ADC Range and Resolution: SW controlled AGC

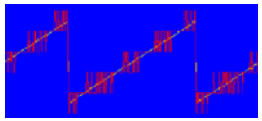
Choose from a selection of AD channels depending on signal energy



ADC accuracy optimization: Dithering

Add Noise Level of ½ LSB to signal
Average over number of samples

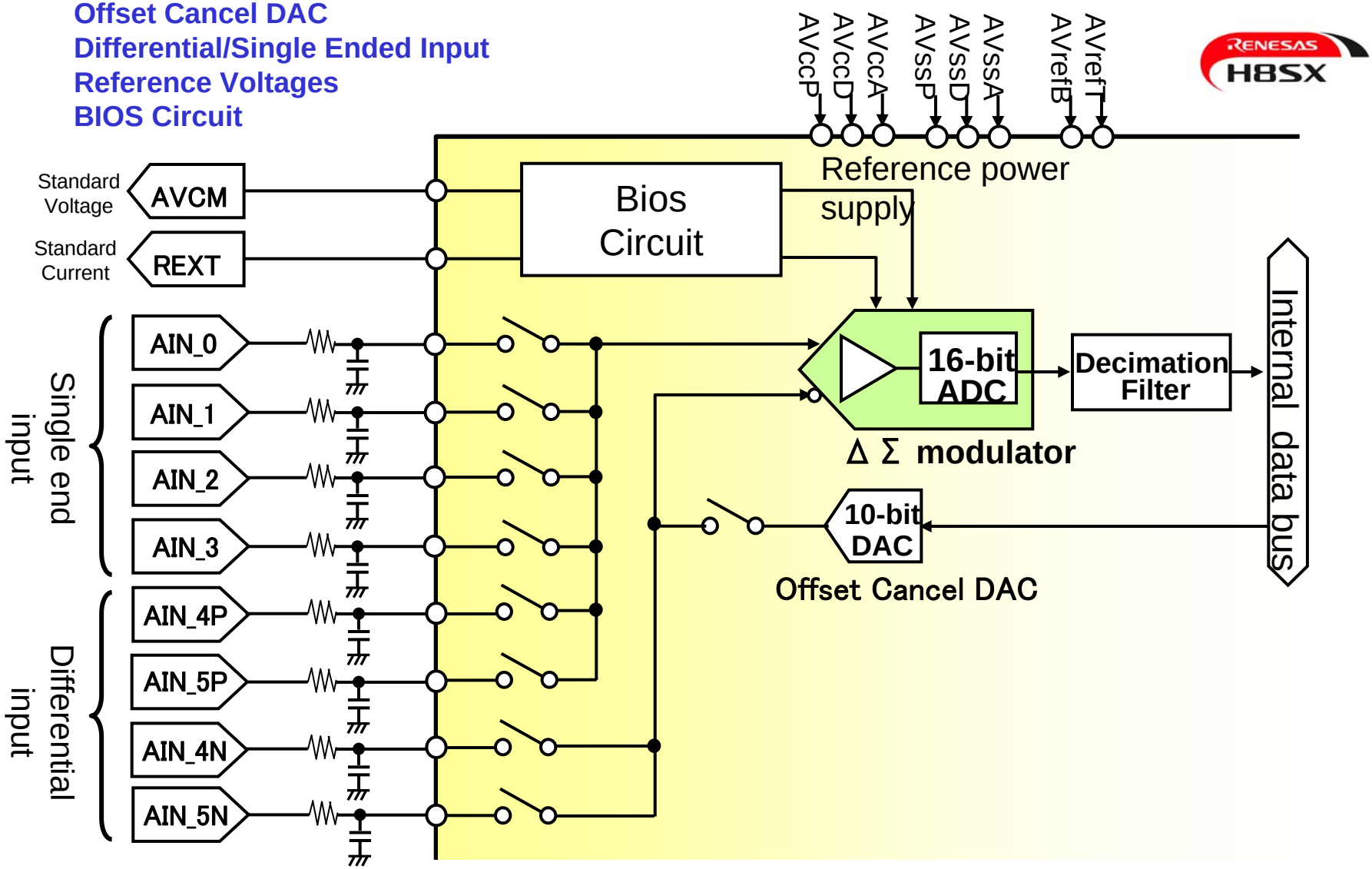




(by Bob Maastra, Interstellar Research)

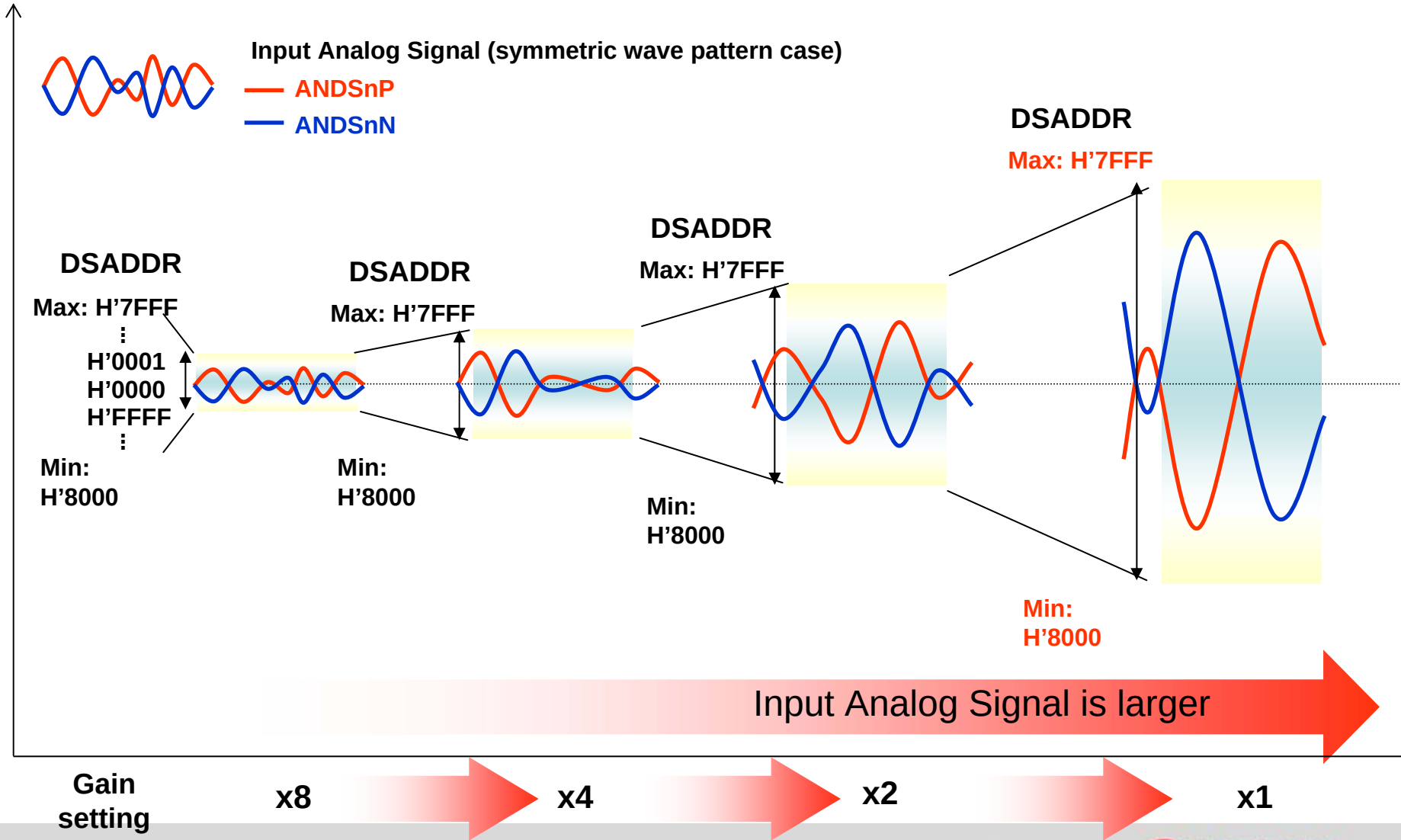
H8SX/1622 with full featured high precision ADC

- 16bit ΣΔ-ADC
- Offset Cancel DAC
- Differential/Single Ended Input
- Reference Voltages
- BIOS Circuit



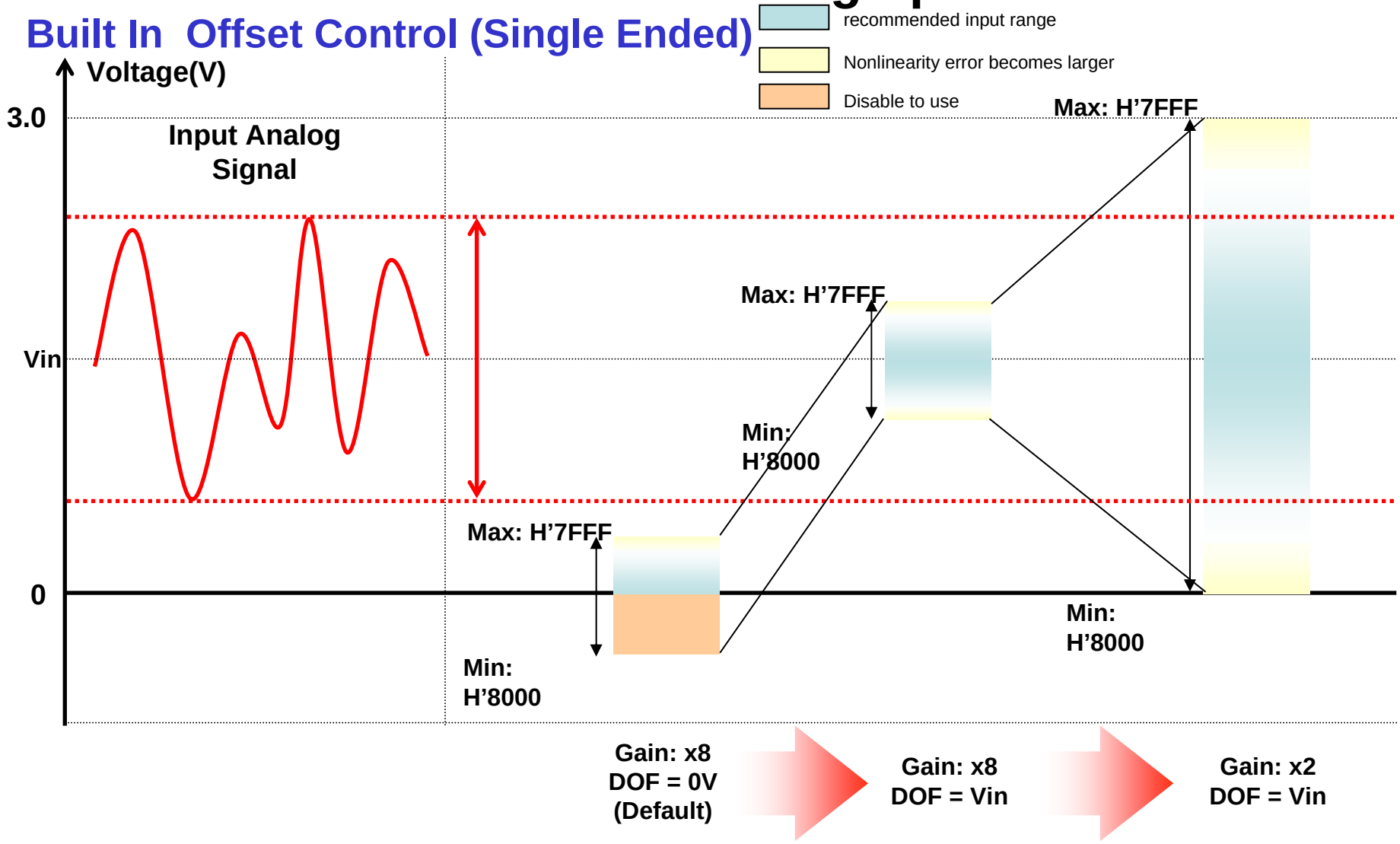
H8SX/1622 with full featured high precision ADC

built in AGC



H8SX/1622 with full featured high precision ADC

Built In Offset Control (Single Ended)

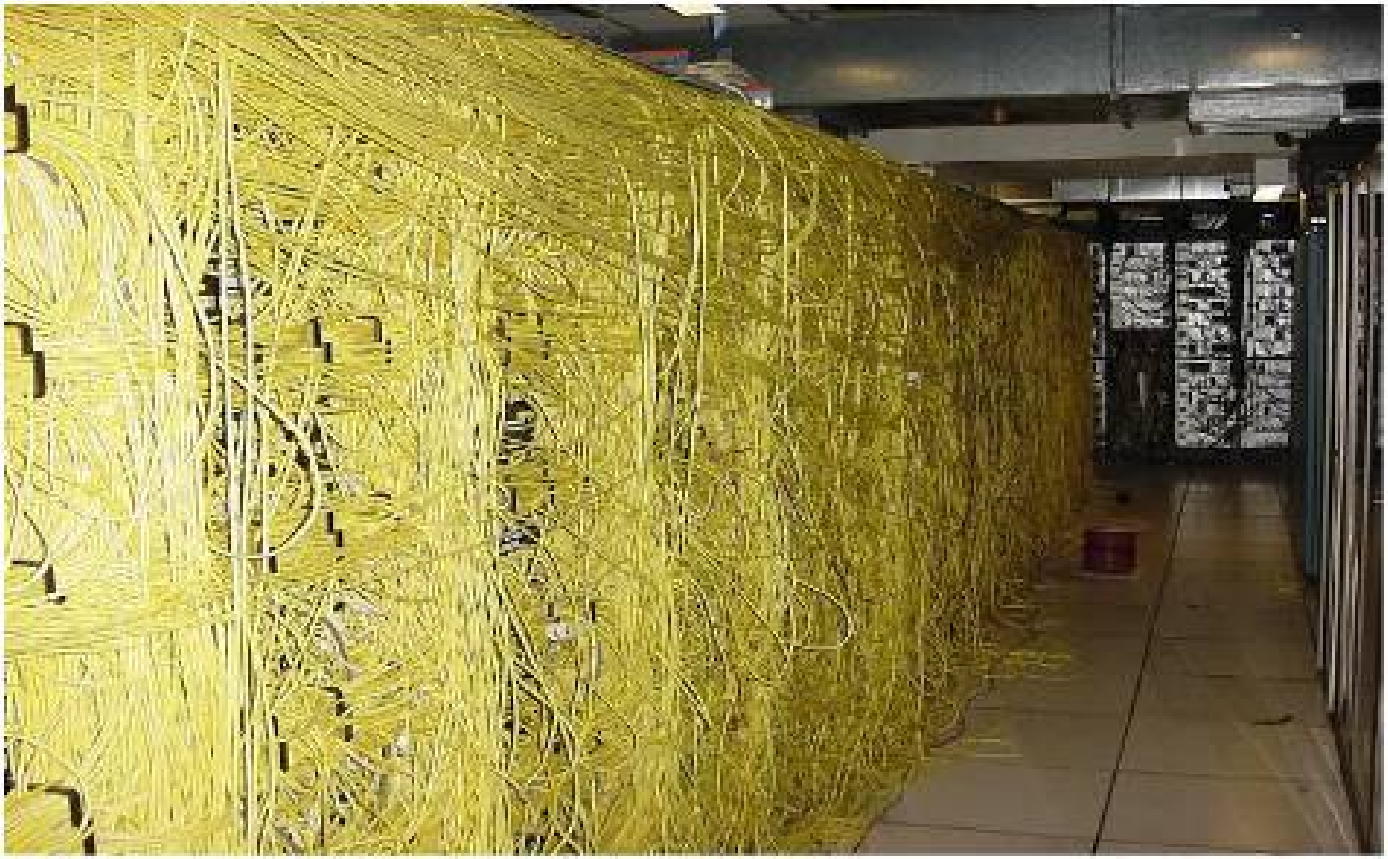


Condition:
AVccP=AVccD=AVccA=AVrefT= 3.0V
AVssP=AVssD=AVssA=AVrefB= 0V

* DOF: Analog level for offset cancellation (V)
* Vin : Center value of input Analog Signal
* DSADOF: Register value set in DSADOFn[9:0] for the corresponding channel
* AVrefT: ΔΣ reference voltage (high) (V), AVrefT =< AVccA
* AVrefB: ΔΣ reference voltage (low), AVrefB = AvssA

*DOF = DSADOF/2^10 x (AVrefT - AVrefB)

Industrial Networks



Industrial sensor networks: Industrial Ethernet

- Industrial Ethernet
  - Class A
    - Completely TCP/IP and UDP based
    - Ordinary ethernet Controller, Realtime handling by application layer
    - Candidates: Profinet, Modbus
  - Class B
    - Parallel channel for process data, TCP/IP timing controlled by process data driver
    - Ordinary Ethernet Controller
    - Candidates: Profinet-RT, Powerlink, Ethernet/IP
  - Class C
    - Parallel channel for process data, TCP/IP timing controlled by process data driver
    - Special Realtime Ethernet Controller
    - Candidates: Ethercat, Sercos, Profinet-IRT

H8S/2472:

- *176pin BGA, 13mmx13mm, 0,8mm pitch*
- *512KB Flash, 40KB RAM*
- *USB 2.0 Full Speed (480Mbps)*
- *Ethernet MAC/PHY on chip*
- *CRC (choice of 3 polynoms)*
- *34MHz @ 3V operation*
- *RSKH8S2472*

Industrial sensor networks: CAN based

- **DeviceNet**
  - –Open Standard (Open DeviceNet Vendor Association)
  - –Developed by Allen-Bradley / Rockwell Automation
  - –Strong in USA and Asia
  - –Based on CIP „Common Industrial Protocol“ (same as Ethernet/IP)
- **CANOpen**
  - –Developed by Bosch
  - –Maintained by CiA (CAN in Automation)
  - –European Standard (EN50325-4)
  - –Strong in Europe

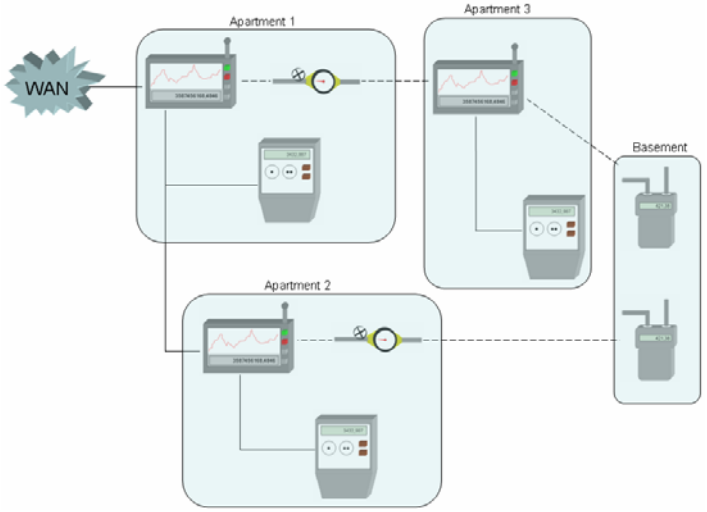
Renesas product selection	R8C/22,23	M16C/29	M16C/6N4,N5 M16C/6NLN, KM	M32C/87	R32C/117* R32C/118*	SH7286
CAN channels	*1*	*1*	*Up to 2*	*Up to 2*	*Up to 3*	*1*
On Chip Flash	*64KB*	*128KB*	*256KB*	*1MB*	*1MB*	*1MB*
Pin	*48*	*64~80*	*100*	*100~144*	*100~144*	*176*
RSK	*RSKR8C23*	*RSKM16C29*	*RSKM16C6NK*	*RSKM32C87*	*RSKR32C118**	*RSK2SH7286**

Industrial sensor networks: 802.15.4 based

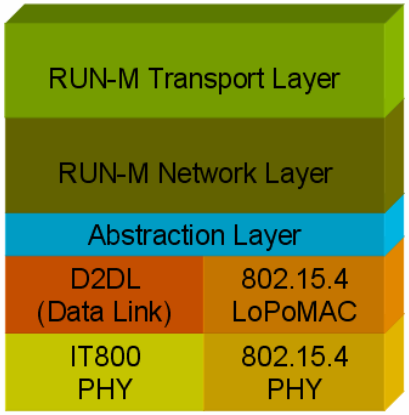
- **WiHART**
  - Wireless Highway Addressable Remote Transducer
  - developed 2007
  - Based on 802.15.4 in ISM (2,4G band)
  - DSSS, channel access by TDMA/CSMA
  - down compatible to wired standard HART (developed 1980‘s)
- **IEEE1451**
  - Smart Transducer Protocol
  - Unified data format (TEDS format)
  - Different standard cover different available protocols
    - » DOT 0: Basic format
    - » DOT 5: Bluetooth, ZigBee, WiFi, RFID, 6LowPAN, etc.
  - Unified compiler and unified compliance testing
  - Seemless internet addressing by gateway
- **ISA100.11a**
  - Created by industry for process automation
  - based on 802.15.4, ISM band (2,4GHz), time sync‘d channel hopping
  - NWL frame format compatible to 6LowPAN, easy gatewaying to TCP/IP world
  - Can tunnel any protocol

Renesas product selection	**RZB-CC16C-ZDK**	**Small IEEE 802.15.4 MAC**
Description	*ZigBee Development Kit, 2,4GHz RF, M16C/2x MCU*	*802.15.4 simple MAC Software*

RUN-M: PLC/RF Hybrid protocol for metering



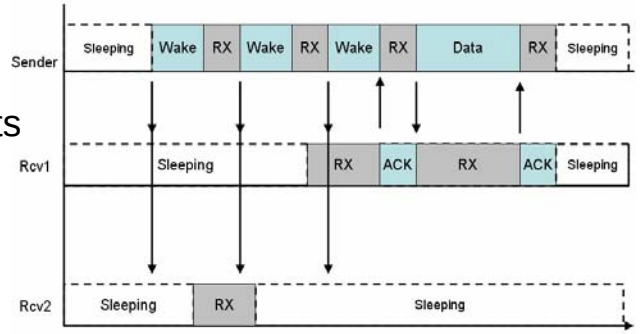
RUN-M™



PLC and RF PHY

Full seemless hybrid approach
No gateway approach

802.15.4 enhancements for low power

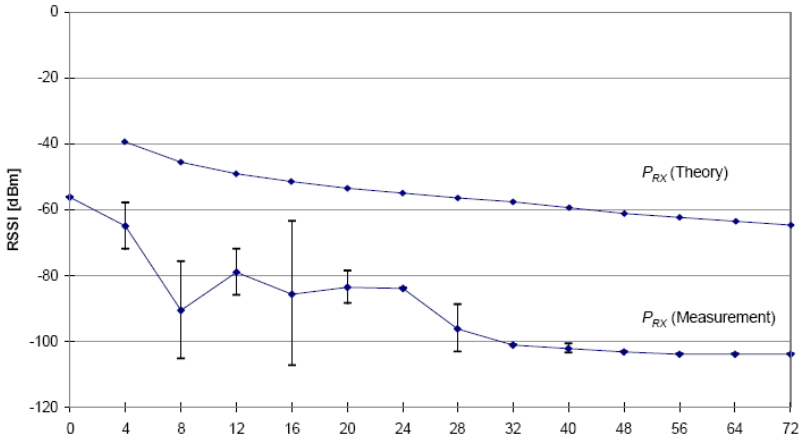


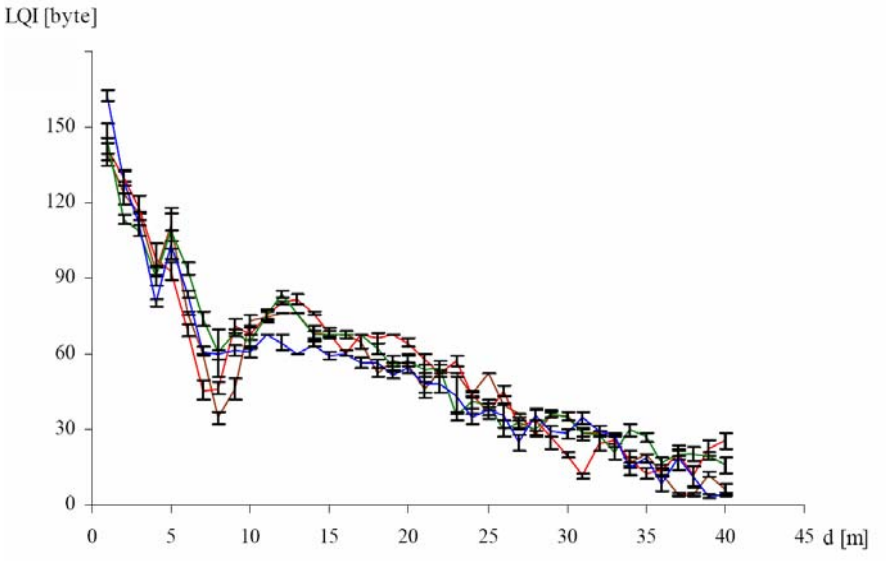
Renesas product selection	**M16C/6S**	**RUN-M**
Description	*M16C CPU Built-In PLC modem based on extreme robust DCSK modulation*	*RUN-M Software Evaluation Version Full Version*

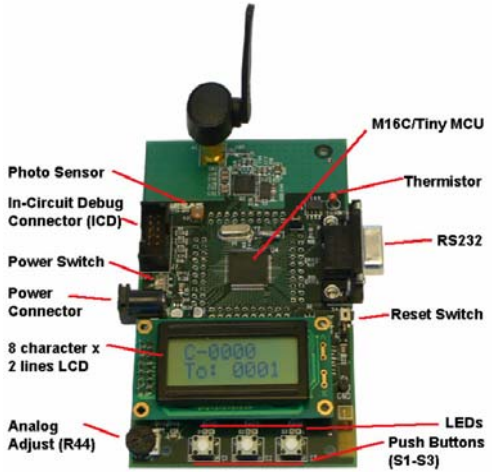
802.15.4 Device as Locating Sensor

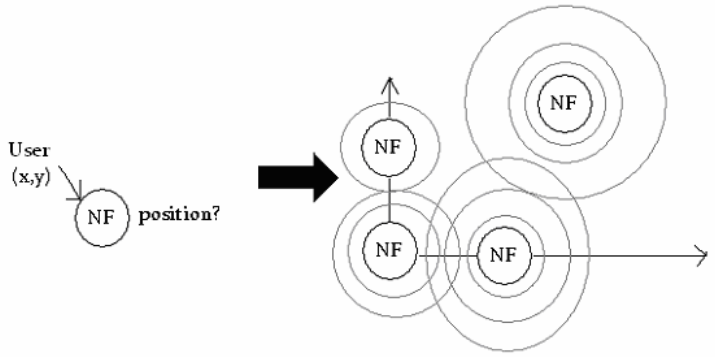
Polytech'Clermont-Ferrand

Student Thesis by Mrs. Fanny Abrahamse, Poltech Clermont-Ferrand, France
At Renesas Ratingen, Germany
5~7/2008









Summary

- Sensor networks for industrial applications have different requirements to sensor networks for consumer applications.
- System concept and component selection must be tuned to the specific sensor application.
- Expert knowhow is needed to achieve extreme low power consumption and high sensor resolution.
- Modern industrial sensor networks must be able to „wrap“ a number of protocols and must offer a selection of PHY layers.
- Renesas offers microcontrollers, software and solutions for many industrial sensor network applications.

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