AMANDA

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AutonoMous self powered miniAturized iNtelligent sensor for environmental sensing anD asset tracking in smArt IoT environments

AMANDA Project – 2nd Webinar

Thermal comfort monitoring scenario & Microdul MS1089 ultra low power temperature sensor

Martin Schellenberg
Microdul AG
Zürich, Switzerland

MICRODUL
Customized Swiss Microelectronics

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Introduction

Microdul AG, Zürich, Switzerland

- Microelectronics SME, ~ 90 employees
- Modules & Thick-film businesses with production line in house
- Fabless Semiconductor department
  - ASICs: ultra low power, mixed signal
  - Standard products: temperature sensing, capacitive sensors
- AMANDA: contribution of 2 ICs
  - Temperature sensor MS1089, as discussed later
  - Capacitive sensor MS8892 with dedicated system wake-up features

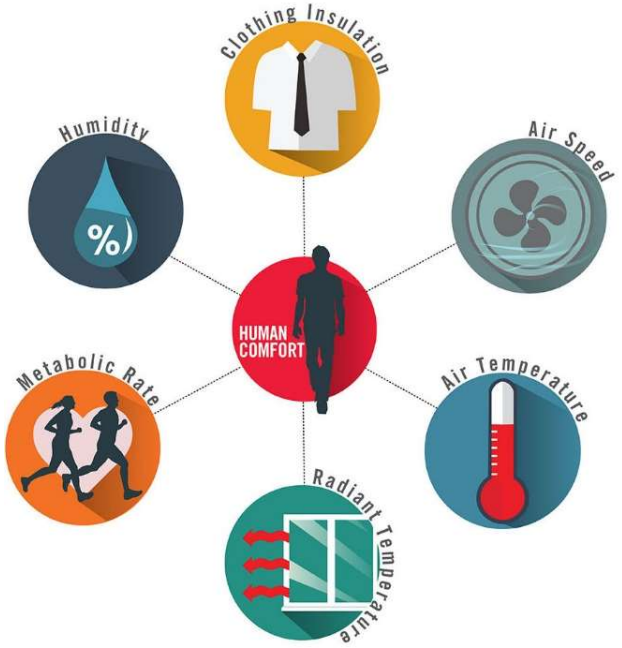
Agenda

- Introduction
- AMANDA: the thermal comfort monitoring scenario
- The Microdul MS1089 temperature sensor IC
  - The advances over the state of the art
  - The best-in-class power consumption
  - The temperature measurement performance
  - Some development milestones

Scenario SC01: Environment and thermal comfort monitoring

Thermal comfort (or Human comfort) is the condition of mind which expresses satisfaction with the thermal environment and is assessed by subjective evaluation. Its variables are:

- Air temperature
- Air speed
- Humidity
- Metabolic Rate
- Clothing Insulation
- Radiant temperature



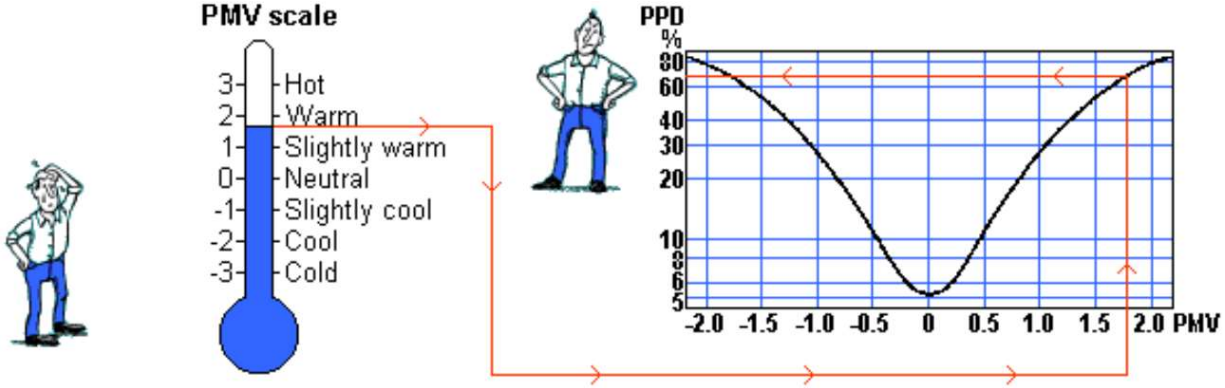
Scenario SC01: Environment and thermal comfort monitoring

PMV & PPD (ASHRAE 55)

The **PMV** (predicted mean vote) scale is a seven-point thermal-sensation scale ranging from -3 (cold) to +3 (hot), where 0 represents the thermally neutral sensation

The **PPD-index** (predicted percentage of dissatisfied) predicts the people that are dissatisfied in a given thermal environment

$$PPD = 100 - 95 \cdot e^{-(0.03353 \cdot PMV^4 + 0.2179 \cdot PMV^2)}$$



ASHRAE 55 defines PMV calculations, based on parameters like: air temperature, radiant temperature, air speed, rel. humidity, metabolic rate, clothing isolation, etc

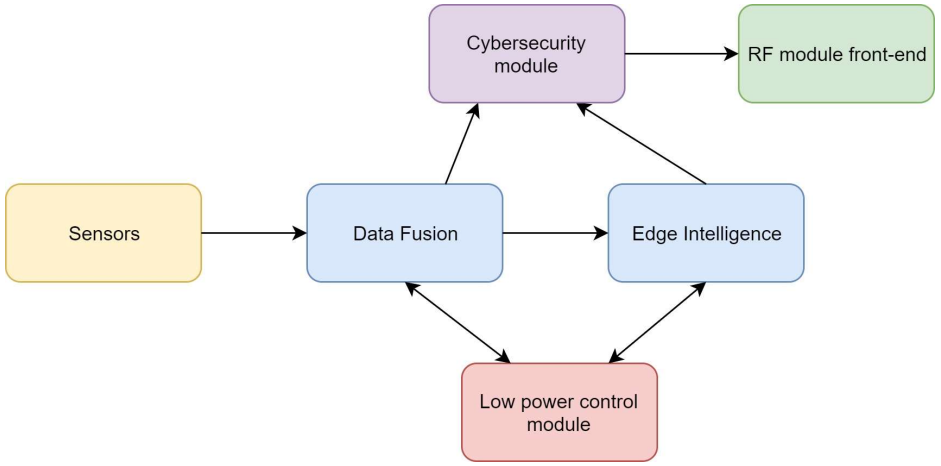
Scenario SC01: Environment and thermal comfort monitoring
Implementation aspects

Used components in SC01

- ✓ Solar harvester
- ✓ Battery
- ✓ PMIC
- ✓ Touch sensor
- ✓ RTC
- ✓ MCU
- ✓ FRAM
- ✓ BLE
- ✓ LoRa
- ✓ RGB LED
- ✓ Atmospheric pressure Sensor
- ✓ Humidity Sensor
- ✓ **Temperature sensor**

Integrated with the ASSC:

- ✓ Sensor Fusion
- ✓ Edge Intelligence
- ✓ Low Power Module



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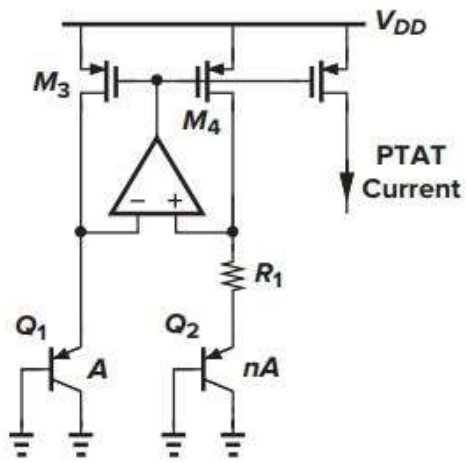
Microdul MS1089 temperature sensor
Silicon temperature sensing



$$VBE = \frac{kT}{q} \cdot ln\left(\frac{ID}{IS}\right)$$

- The basic principle of most or all silicon temperature sensors is the temperature dependence of the forward biased **silicon diode**
- This elementary device is available in any standard CMOS technology
- Implementation differences are, among others
  - Measurement electronics (oscillators, A/D converters, etc.)
  - Linearity correction
  - Calibration method (accuracy, temperature range)
  - Power consumption
- Microdul has this know-how and has developed several temperature sensors and monitors based on this technology

Microdul MS1089 temperature sensor
State-of-the-art & GAP

Parameter	MS1088 Microdul	TMP117 TI	AS6200 AMS	STS35 Sensirion	Si7053 SiLabs
I_{active} [µA]	75	135	50	600	90
I_{idle} [nA]	20	150	100	200	60 (620 @ 85°C)
$I_{1\ Hz}$ [µA]	4.1	3.5 - 16	1.5	1.7	0.27
$I_{1/60\ Hz}$ [nA]	80	210	130 (40)	225	63
t_{conv} [ms]	50	16	32	2.5	2.4
E_{unit} [µJ][1]	11.25	7.1	4.8	5.0	0.72
$A_{10/40}$ [°C]	0.3 / 0.5	0.1	0.4	0.1 typical 20 ~ 60 °C	-
$A_{-20/85}$ [°C]	-	< 0.2	-	0.3 max -40 ~ 90 °C	-
$A_{-40/120}$ [°C]	1.5 / 2.0	< 0.3	1.0	0.6 max -40 ~125 °C	0.3 max -40 ~125 °C
V_{sup} [V]	2.4 - 3.5	1.8 - 5.5	1.8 - 3.6	2.4 - 5.5	1.9 - 3.6
Package type & size [mm]	QFN 16 3 x 3	WSON 6 2 x 2	CSP 6 1.5 x 1.0	DFN 8 2.5 x 2.5	DFN 6 3 x 3
2nd package type & size [mm]	CSP 12 1.39 x 0.93	-	-	-	-
Price [$] @1k	-	2.99 (Arrow)	0.81 (Digikey)	1.25 (Digikey)	1.45 (Arrow)

State of the Art analysis

- Large number of temperature sensors on the market
- Differing in many parameters: active & idle power consumption, price, accuracy, temperature range, package, target application

Targets for the MS1089 chip for AMANDA

- Lowest avarage power consumption in the marketplace
- Smallest possible package size
- Low cost (eg. one point calibration)

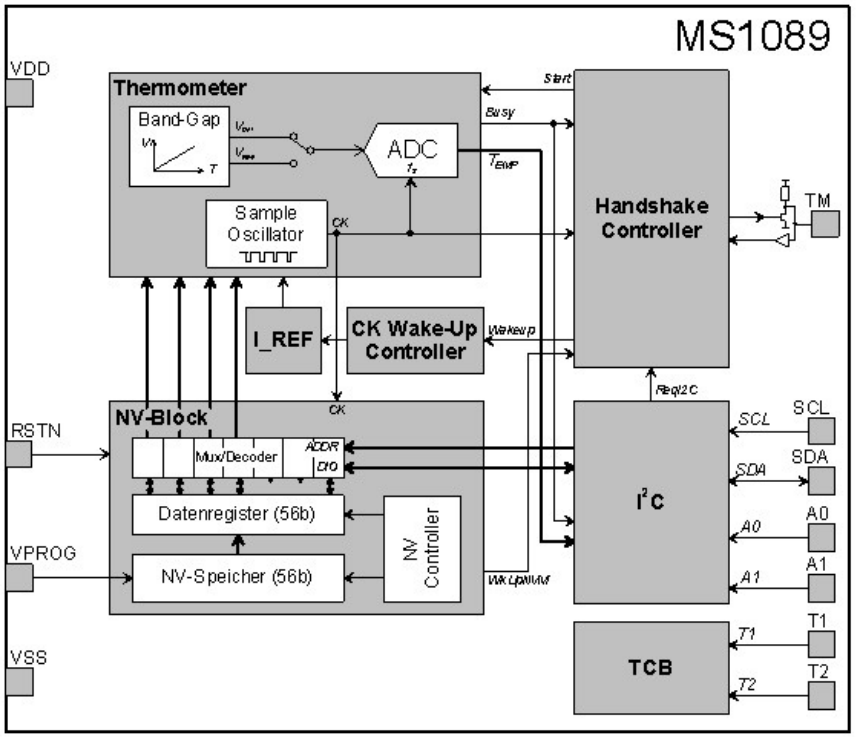
Microdul MS1089 temperature sensor
Design implementation

Methods to reach lowest power consumption:

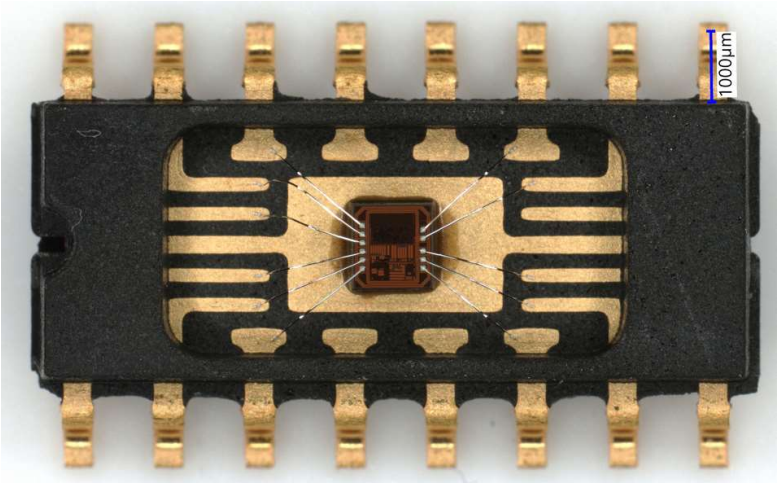
- Reduction of measurement duration
  => 3 resolution settings
- Reduction of current consumption during the measurement => circuit optimisations
- Reduction of static current between the measurements
  => shutdown of all circuit parts between measurements

Additional target to fit the power supply range of the AMANDA ASSC

- Extension of the supply voltage range down to 1.8V



Microdul MS1089 temperature sensor
Wafer & samples production



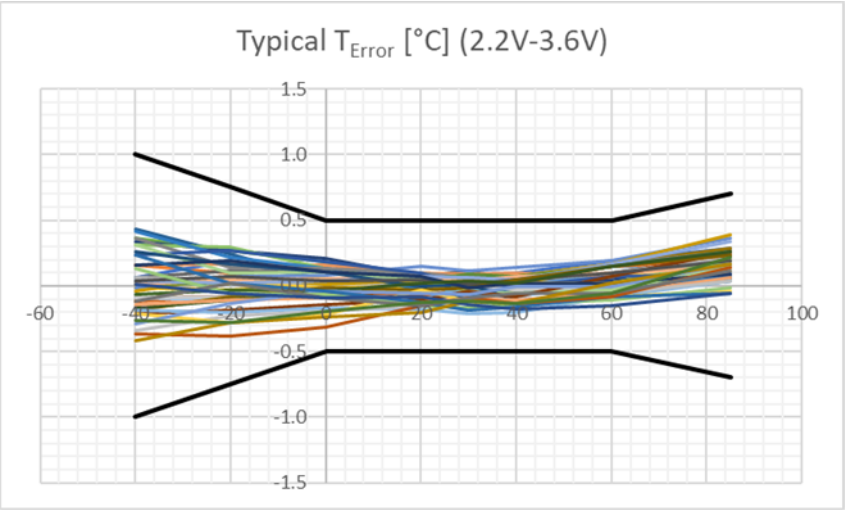
SOIC-16 prototype package

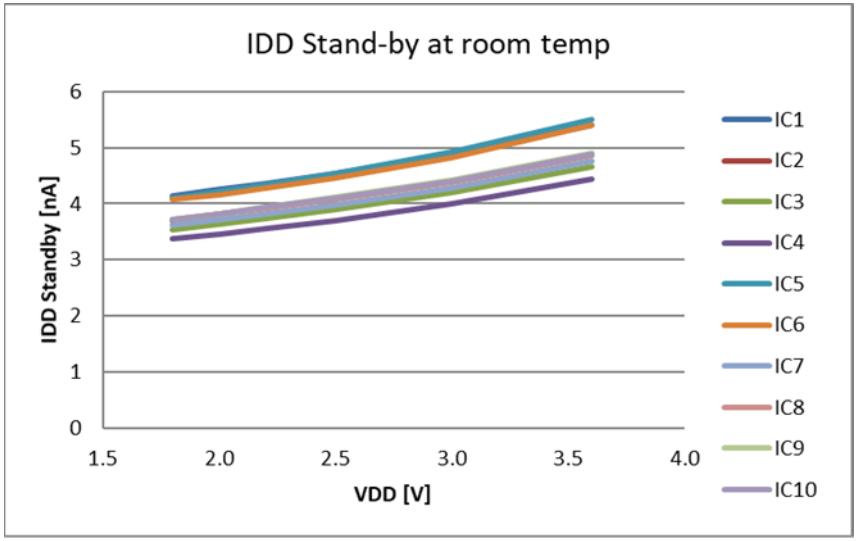
- Fast in-house assembly
- Easy handling
- Evaluation & calibration parameters
- Prototypes for unconstrained ASSC

Miniaturised CSP package

- Small: 1.22x1.15 mm^2
- Used for the miniaturised AMANDA card
- Ready for the Microdul customers in Q1/22

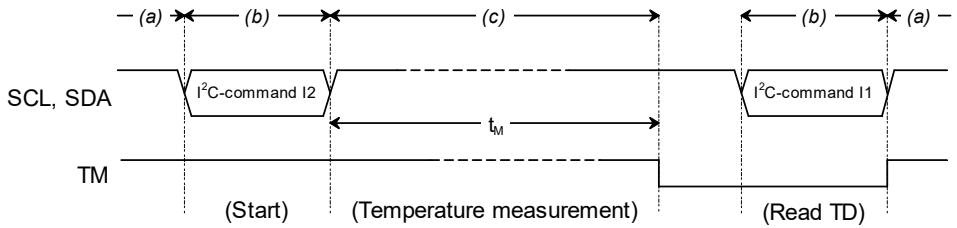
Microdul MS1089 temperature sensor
Electrical evaluation results





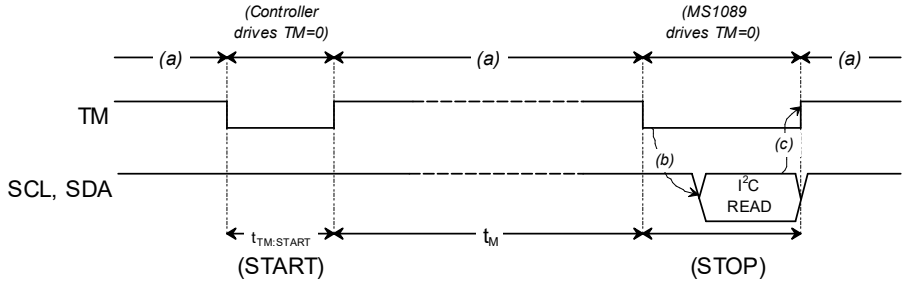
$I_{DD:AV}$	Average operating current	11 bit (0.1 °C), note 1		27		nA
		12 bit (0.05 °C), note 1		55		
		13 bit (0.025 °C), note 1		110		

Microdul MS1089 temperature sensor
Application hints



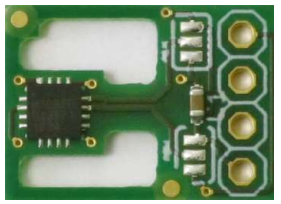
Notes:
(a) Ultra low-power
(b) I²C communication
(c) Measurement mode

Temperature measurement with I²C



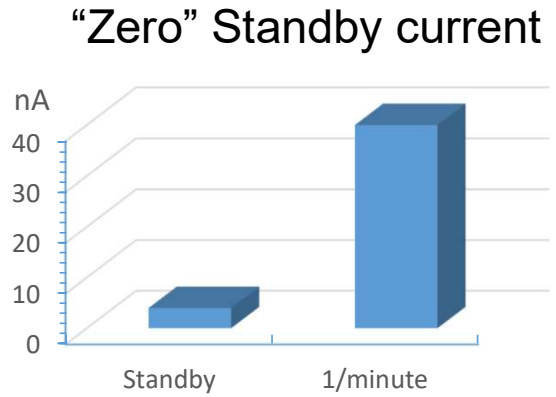
Notes:
(a) Controller sets TM=HiZ ; MS1089 internal pull-up sets TM='1'
(b) Controller detects TM=0 and sends I²C-Read command
(c) MS1089 acknowledges I²C-Read command and releases TM

Temperature measurement with the handshake protocol



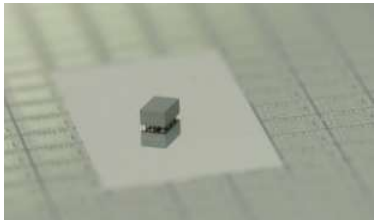
For fast adaptation to a changing ambient temperature and a good accuracy, the sensor (here in QFN16) should be thermally isolated from the remaining components.

Microdul MS1089 temperature sensor
Summary



Small

CSP 1.22 x 1.15mm



MS1089 features, summary:

- "Zero standby" (~5nA) current in sleep mode
- Average 27nA at one measurement per minute
- 70µA peak current during measurement
- Supply voltage range 1.8V – 3.6V
- Accuracy ±0.3°C from 10°C to 50°C
- Digital handshake line to save further power
- -40°C to 85° operating temperature range
- Miniature package size 1.22mm x 1.15mm
- Best choice for autonomous systems

Further information at:
www.microdul.com / info@microdul.com

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Thank you

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martin.Schellenberg@microdul.com

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Microdul MS1089 temperature sensor
MS1089 and AMANDA

Benefits for AMANDA using the MS1089

- Lowest power consumption enables a longer battery life between recharge opportunities and/or in low light conditions
- In most of the defined use cases for AMANDA, temperature has to be measured and the MS1089 is used for it
- The small package size ideally fits the miniaturized AMANDA card
- Chip-scale samples available in January 2022