Hardware para Redes de Sensores Sem Fio: Família Motes

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Mestrando em Engenharia Elétrica - CPDEE/UFMG

Responsável pelo Hardware do Projeto SensorNet

Agenda

1. Introdução
2. A Família Motes
3. MPR400 (MICA2)
4. MPR500 (MICA2DOT)
5. MTS101
6. MTS300/MTS310
7. MTS400/MTS410
8. Conclusões
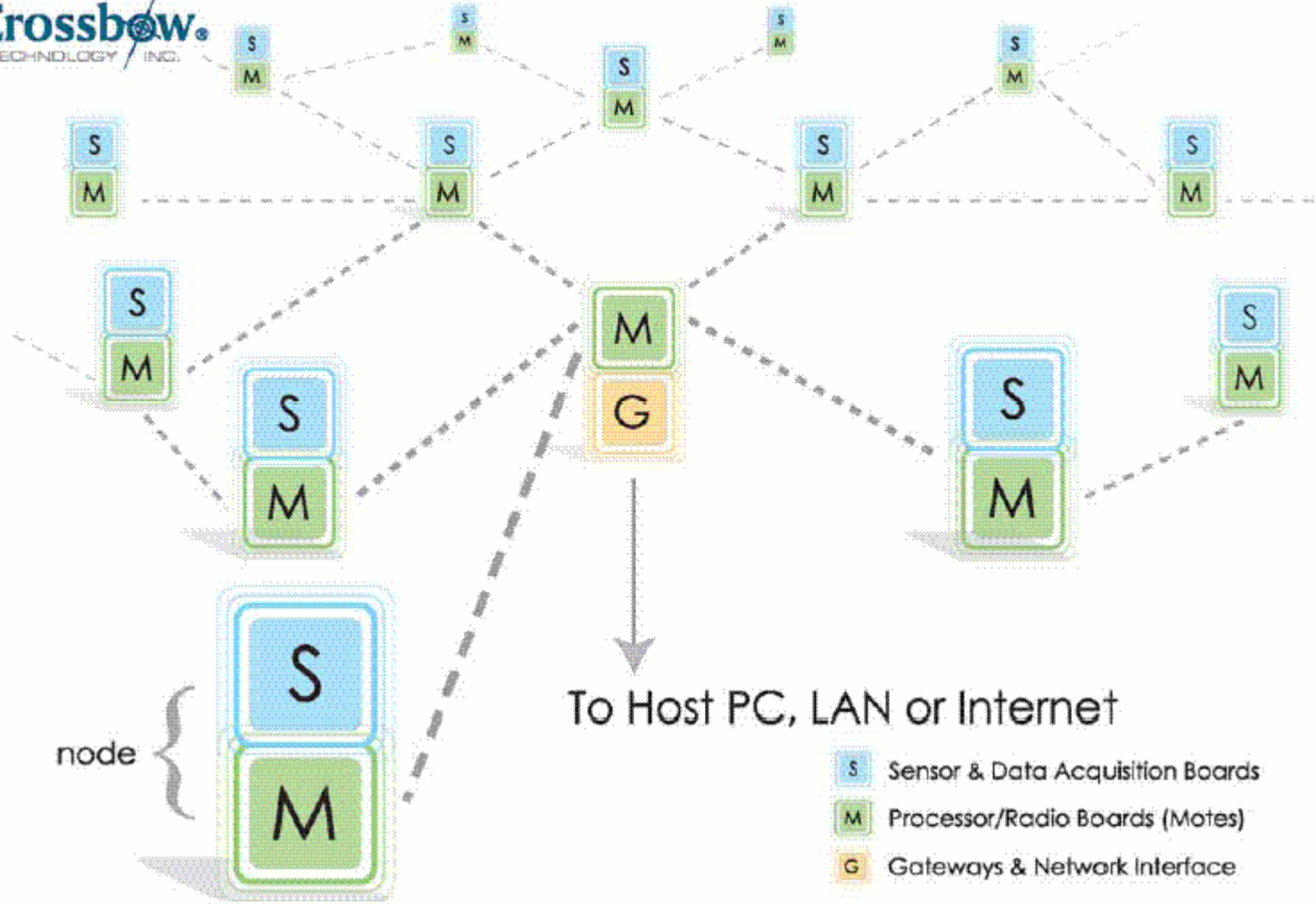9. Referências bibliográficas

Introdução

- MOTIVAÇÃO:

➢ **Fornecer informações técnicas do hardware disponível para o desenvolvimento de aplicações em RSSF's;**

➢ **Apresentar os projetos e propostas de desenvolvimento de hardware para RSSF's**

A Família Motes

Crossbow® TECHNOLOGY / INC.

To Host PC, LAN or Internet

node {

S — Sensor & Data Acquisition Boards
M — Processor/Radio Boards (Motes)
G — Gateways & Network Interface

A Família Motes

A Família Motes

Table 1-1. Crossbow's Sensor and Data Acquisition Boards.
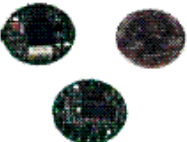
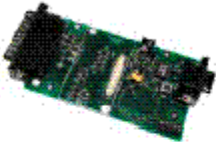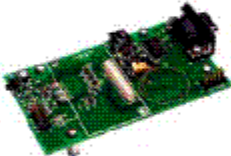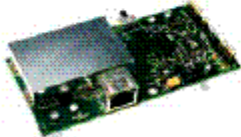| Chapter	Crossbow Part Name	Motes Supported	Sensors and Features
2	MTS101CA	MICA, MICA2	Light, temperature, prototyping area
3	MTS300CA	MICA, MICA2	Light, temperature, microphone, and buzzer
3	MTS310CA	MICA, MICA2	Light, temperature, microphone, buzzer, 2-axis accelerometer, and 2-axis magnetometer
4	MTS400CA	MICA2	Ambient light, relative humidity, temperature, 2-axis accelerometer, and barometric pressure
4	MTS420CA	MICA2	Same as MTS400CA plus a GPS module
5	MTS510CA	MICA2DOT	Light, microphone, and 2-axis accelerometer
6	MDA300CA	MICA2	Light, relative humidity, general purpose interface for external sensors
7	MDA500CA	MICA2DOT	Prototyping area

A Família Motes

Mote Processor Radio Platforms ("Motes", MPR Series)

Photo	Crossbow Part ID	Commonly Used Name	Frequency Range	Processor	Radio Transceiver	Nonvolatile Memory
	MPR300 (discontinued) MPR310 (discontinued)	MICA (sometimes refered to as MICA1)	902 to 928 MHz 433.1 to 434.8 MHz	Atmel ATMega128L	RFM TR1000	Atmel AT45DB041B (512 kB)
	MPR400 MPR410 MPR420	MICA2	868 to 870; 902 to 928 MHz 433.1 to 434.8 MHz 313.9 to 316.1 MHz	Atmel ATMega128L	Chipcon CC1000	Atmel AT45DB041B (512 kB)
	MPR500 MPR510 MPR520	MICA2DOT	868 to 870; 902 to 928 MHz 433.1 to 434.8 MHz 313.9 to 316.1 MHz	Atmel ATMega128L	Chipcon CC1000	Atmel AT45DB041B (512 kB)
	MPR2400	MICAz	2400 to 2483.5 MHz	Atmel ATMega128L	Chipcon CC2420 (802.15.4)	Atmel AT45DB041B (512 kB)
	MCS400CA	Cricket	433.1 to 434.8 MHz	Atmel ATMega128L	Chipcon CC1000	Atmel AT45DB041B (512 kB)

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A Família Motes

Gateways and Network Interfaces (MIB or SPB Series)

Photo	Crossbow Part ID	Description	Mote/Board Connectors	Programming Port	Data Port
	MIB500 (discontinued)	Parallel Port Programmer	MICA, MICA2 (51-pin connector, top-side) MICA-Series sensor boards (51-pin connector, bottom-side) MICA2DOT (19-pin circular connector, bottom-side)	Parallel	Serial (RS-232)
	MIB510	Serial Port Programmer	MICA, MICA2 (51-pin connector, top-side) MICA-Series sensor boards (51-pin connector, bottom-side) MICA2DOT (19-pin circular connector)	Serial (RS-232)	Serial (RS-232)
	MIB600	Ethernet Programming Board	MICA, MICA2 (51-pin connector) MICA2DOT (only with extension cable)	Ethernet	Ethernet
	SPB400	Stargate, Xscale Platform	*Main board:* PCMCIA, Compact Flash, MICA2 (51-pin connector) *Daughter card:* USB, RS-232, Ethernet, External power	With host PC: RS-232 or Ethernet (using ssh)	Various

A Família Motes

Mote Processor Radio Platforms ("Motes", MPR Series)

Model Number	Price(USD)
MPR400CB MICA2,900MHz	$ 150.00
MPR500CA DOT,900MHz	$ 115.00
MPR2400CA MICAZ, 2.4 GHz	$ 150.00
MCS410CA CRICKET MOTE, RS232 BEACON	$ 195.00

A Família Motes

Sensor and Data Acquisition Boards (MTS and MDA Series)

Model Number	Price(USD)
MTS101CA MOTE,SENSOR	$ 90.00
MDA300CA MICA DATA ACQ CARD	$ 275.00
MTS400CA - WEATHER BOARD	$ 250.00
MTS420CA - GPS WEATHER BOARD	$ 375.00
MTS300CA AUDIO SENSOR	$ 120.00
MTS310CA MAG-ACCEL SENSOR	$ 210.00
MDA500CA MICA2DOT SNSR BRD	$ 30.00
MTS510CA - MICA2DOT SENSOR BOARD	$ 120.00

CPDEE   30/11/04

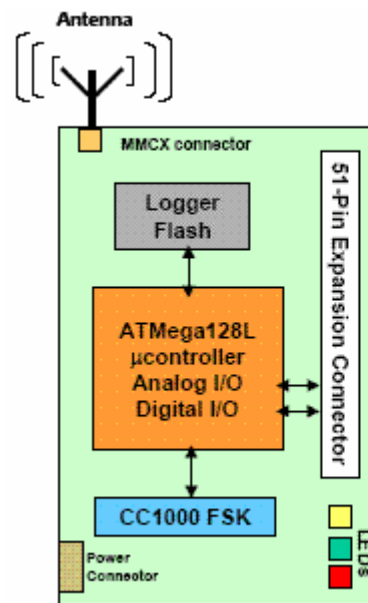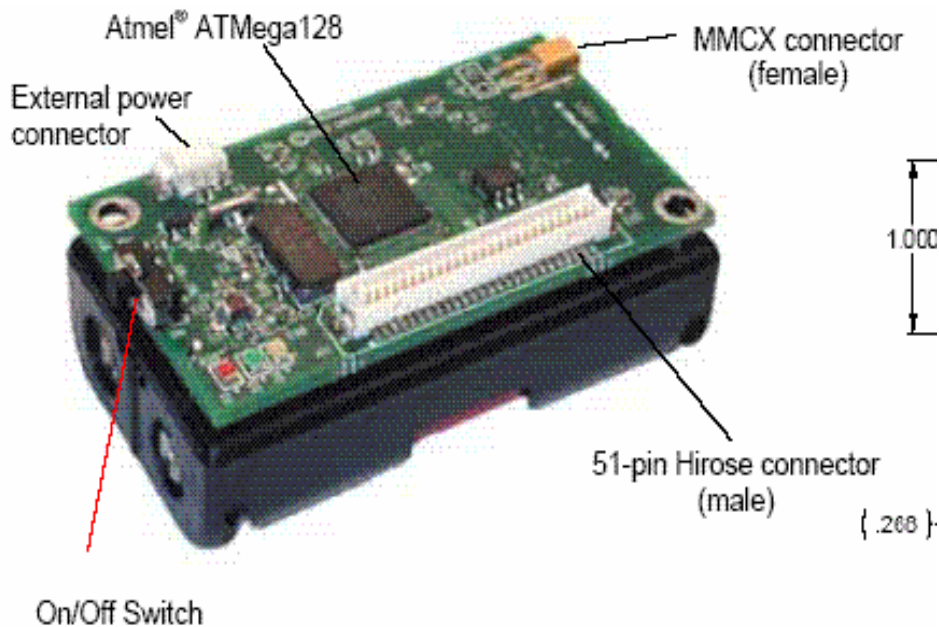**Centro de Pesquisa e Desenvolvimento em Engenharia Elétrica**

A Família Motes

Gateways and Network Interfaces (MIB or SPB Series)

Model Number	Price(USD)
MIB510CA	**$ 95.00**
MIB600CA	**$ 349.00**
SP-KIT400 STARGATE BASIC KIT	$ 695.00

MPR400 (MICA2)/MPR500 (MICA2DOT)

Atmel® ATMega128

External power connector

MMCX connector (female)

On/Off Switch

51-pin Hirose connector (male)

1.000

(.268)

Antenna

MMCX connector

Logger Flash

ATMega128L µcontroller Analog I/O Digital I/O

CC1000 FSK

51-Pin Expansion Connector

Power Connector

LEDs

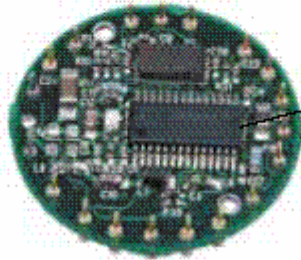| Feature	Chapter
Battery / Ext. Power	6
Radio	7
Antenna	8
Data Flash Logger	9
Atmega128	10
Expansion Connector	11

MPR400 (MICA2)/MPR500 (MICA2DOT)
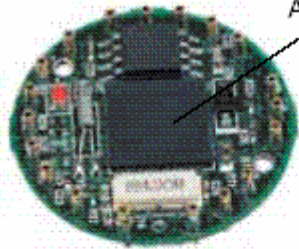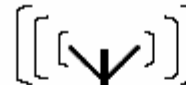
Atmel® ATMega128

(a) Top-side

Chipcon® CC1000

(b) Bottom-side

19 peripheral pins

Antenna

Logger Flash

ATMega128L
µcontroller
Analog I/O
Digital I/O

Freq.
Tunable
Radio

25 mm

Feature	Chapter
Battery / Ext. Power	6
Radio	7
Antenna	8
Data Flash Logger	9
Atmega128	10
Expansion Connector	11

Centro de Pesquisa e Desenvolvimento em Engenharia Elétrica

MPR400 (MICA2)/MPR500 (MICA2DOT)

- **MICROCONTROLADOR ATMEGA128L**

➤ **Microcontrolador de 8 bits (Low-Power);**

➤ **Alimentação: 2,7-5,5V;**

➤ **Arquitetura RISC avançada: 133 instruções (a maioria em um ciclo de clock);**

➤ **128 KB Flash, 4KB EEPROM, 4KB SRAM;**

➤ **512 KB Flash externa;**

MPR400 (MICA2)/MPR500 (MICA2DOT)

- MICROCONTROLADOR ATMEGA128L

➢ 2 timer/counters de 8 bits;

➢ 2 canais PWM de 8 bits;

➢ 6 canais PWM c/ resolução programável de 2 a 16 bits;

➢ 53 portas de I/O programáveis;

➢ ADC de 10 bits com 8 canais multiplexados;

➢ Faixa de frequências de 0-8 MHz:

✓ MICA2: 7,3728 MHz;

✓ MICA2DOT: 4 MHz.

Conversor Analógico-Digital

• Aproximação sucessiva;

• 10 bits de resolução;

• 8 canais multiplexados:

➢ 8 canais independentes;

➢ 7 canais diferenciais (ADC1 – terminal negativo comum);

➢ 2 canais diferenciais com ganho programável (ADC1, ADC0 e ADC3, ADC2): 1x, 10x (resolução de 8 bits) ou 200x (resolução de 7 bits);

• Tempo de conversão: 65-260 μ s;

• 3 opções de tensão de referência.

Conversor Analógico-Digital

$$ADC = \frac{V_{IN} \cdot 1024}{V_{REF}}$$

$$ADC = \frac{(V_{POS} - V_{NEG}) \cdot GAIN \cdot 512}{V_{REF}}$$
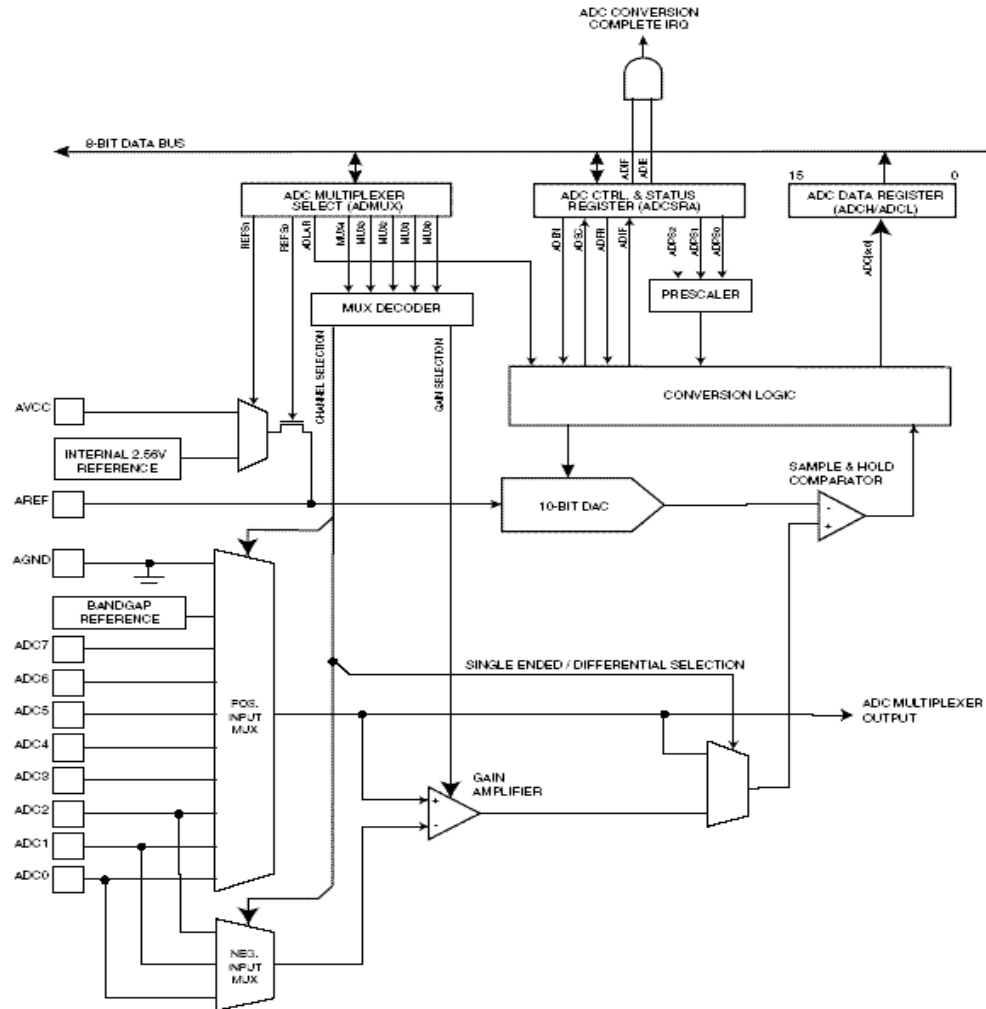
Example:

ADMUX = 0xED (ADC3 - ADC2, 10x gain, 2.56V reference

Voltage on ADC3 is 300 mV, voltage on ADC2 is 500 mV.
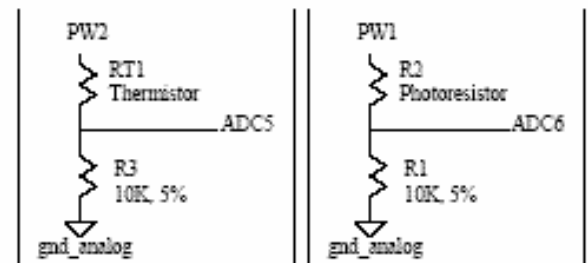
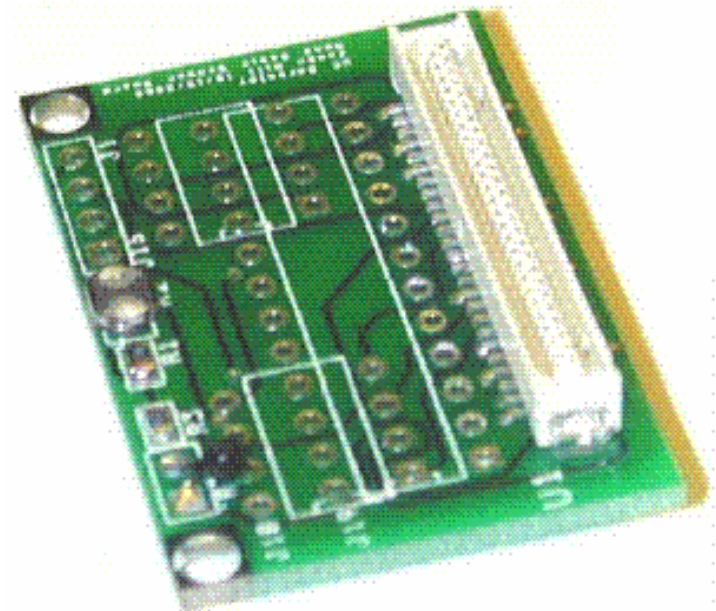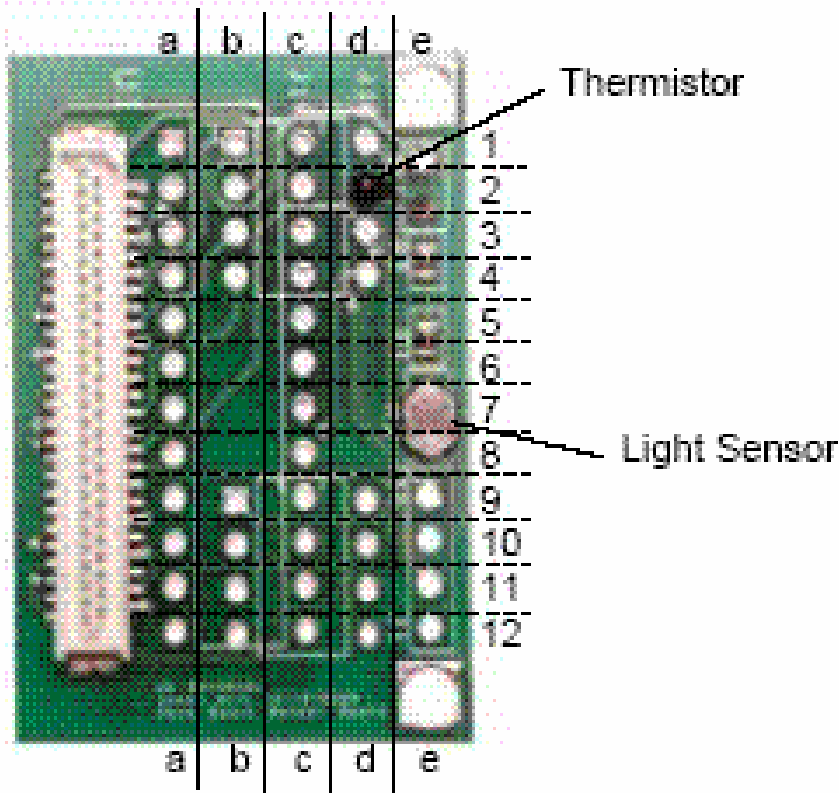ADCR = 512 * 10 * (300 - 500) / 2560 = -400 = 0x270

MTS101

Sensor de Temperatura

Thermistor, (YSI 44006, http://www.ysi.com)

- Faixa de operação recomendada: -80 a 120°C;

- Constante de dissipação: 1mW/°C;

- Resistência@25°C: 10k;

- Precisão: 0,2°C.

Thermistor, (YSI 44006, http://www.ysi.com)

Table 2-2. *Resistance vs. Temperature, ADC5 Reading*

Temperature (°C)	Resistance (Ohms)	ADC5 Reading (% of VCC)
-40	239,800	4%
-20	78,910	11%
0	29,940	25%
25	10,000	50%
40	5592	64%
60	2760	78%
70	1990	83%

Resistance (RT1 Ohms)

Thermistor, (YSI 44006, http://www.ysi.com)
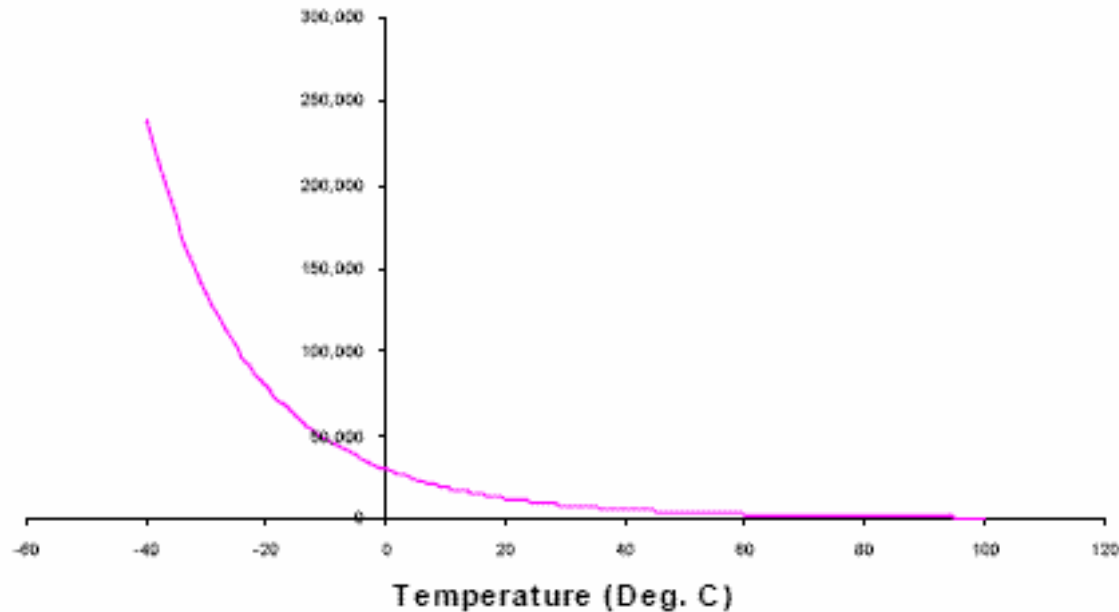
Figure 2-2. Resistance vs. Temperature Graph

Thermistor, (YSI 44006, http://www.ysi.com)

The mote's ADC output can be converted to Kelvin using the following approximation over 0 to 50 °C:

$$1/T(K) = a + b \times \ln(R_{thr}) + c \times [\ln(R_{thr})]^3$$

where:

$R_{thr} = R1(ADC\_FS-ADC)/ADC$

$a = 0.001010024$

$b = 0.000242127$

$c = 0.000000146$

$R1 = 10\ k\Omega$

$ADC\_FS = 1023$, and

ADC = output value from mote's ADC measurement.

Sensor de Luz

Fotocélula de CdSe Clairex - CL94L (http://www.clairex.com/).

Table 2-3. *Light Sensor Specifications.*

Type	Clairex CL94L
R_{ON}	2 kΩ
R_{OFF}	520 kΩ
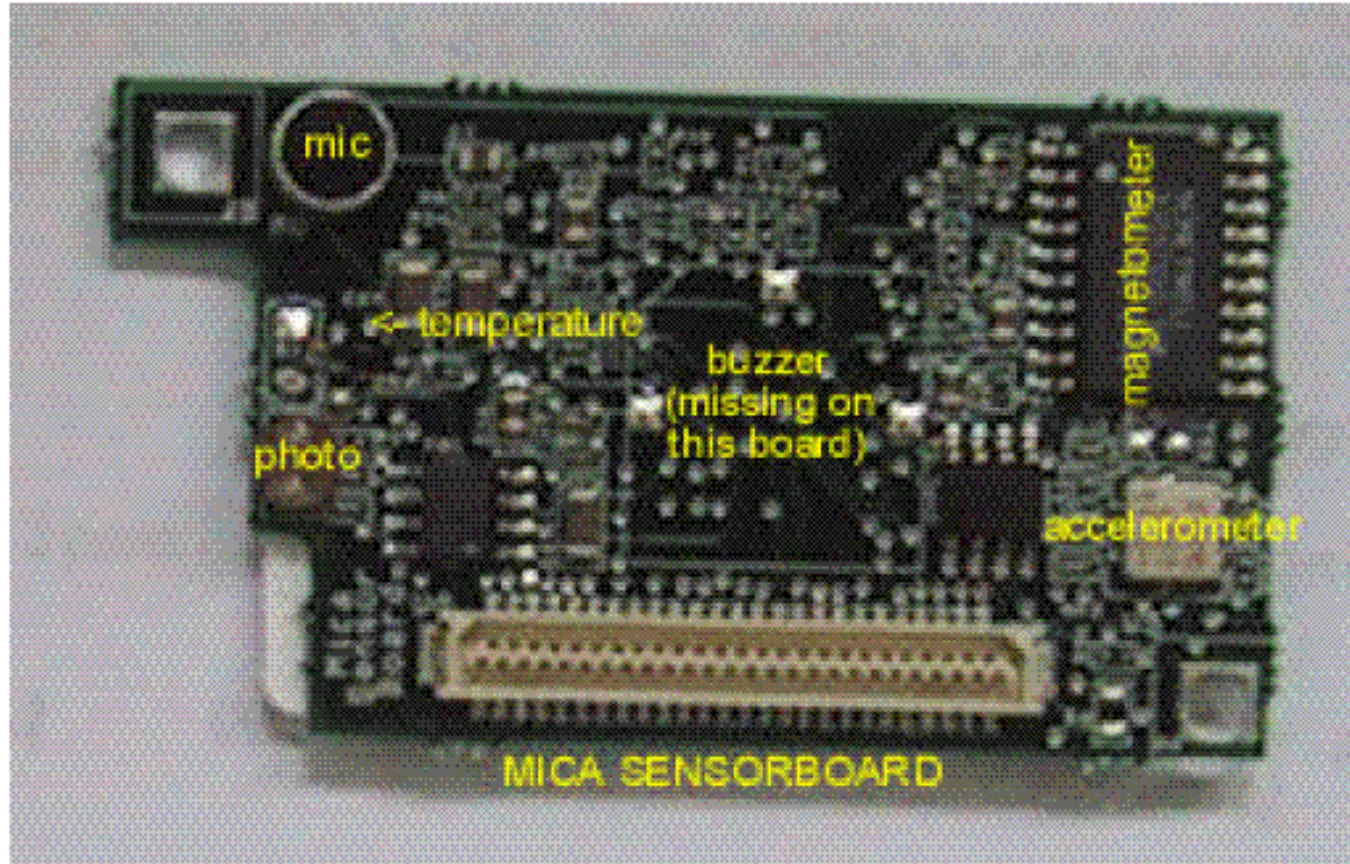
MTS300/MTS310

MTS300/MTS310

- Luz: Clairex CL94L;

- Temperatura: Panasonic ERT-J1VR103J:

➤ Faixa de operação recomendada: -40 a 125°C;

➤ Constante de dissipação: 3mW/°C;

➤ Resistência@25°C: 10k;

➤ Precisão: 0,2°C.
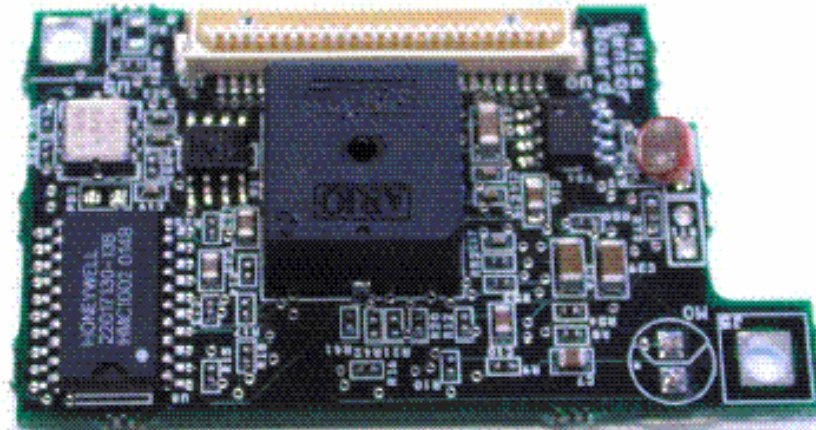
• **Temperatura: Panasonic ERT-J1VR103J:**

Table 3-1. *Voltage, Resistance vs. Temperature.*

Temperature (°C)	Resistance (Ohms)	ADC1 Reading (% of VCC)
-40	427,910	2.3%
-20	114,200	8.1%
0	35,670	22%
25	10,000	50%
40	4090	71%
60	2224	82%
70	1520	87%

- **Temperatura: Panasonic ERT-J1VR103J:**

The mote's ADC output can be converted to degrees Kelvin using the following approximation over 0-50 °C:

$$1/T(K) = a + b \times \ln(R_{thr}) + c \times [\ln(R_{thr})]^3$$

where:

$R_{thr} = R1(ADC\_FS-ADC)/ADC$

$a = 0.00130705$

$b = 0.000214381$

$c = 0.000000093$

$R1 = 10 \text{ k}\Omega$

$ADC\_FS = 1023$

ADC = output value from mote's ADC measurement.

•**Acelerômetro de 2 eixos ADXL202JE:**

(http://www.analog.com)

Table 3-2. *Summary of ADXL202JE Specifications.*

Channels	X (ADC3), Y (ADC4)
G-range	±2 g (1 g = 9.81 m/s^2)
Bandwidth	DC-50 Hz (controlled by C20, C21)
Resolution	2 mG (0.002 G) RMS
Sensitivity	167 mV/G ±17 %
Offset:	2.5 V ±0.4 V

MTS300/MTS310

- **Acelerômetro de 2 eixos ADXL202JE:**

FUNCTIONAL BLOCK DIAGRAM

$A(g) = (T1/T2 - 0.5)/12.5\%$
$0g = 50\%$ DUTY CYCLE
$T2 = R_{SET}/125M\Omega$

•**Magnetômetro de 2 eixos HMC1002:**

(http://www.honeywell.com)
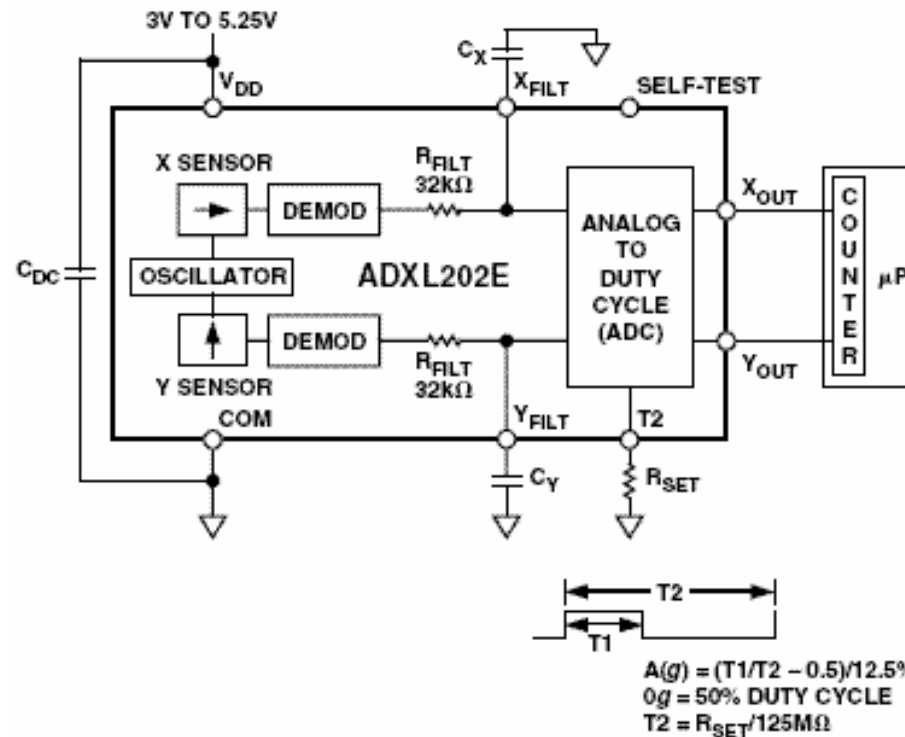
HMC1002—Two-Axis MR Microcircuit

GND1 (A) 1	20 S/R- (A)
OUT+ (A) 2	19 NC
OFFSET- (A) 3	18 GND PLN
Vbridge (A) 4	17 OFFSET (+A)
OUT- (A) 5	16 S/R+ (A)
GND2 (A) 6	15 OFFSET+ (B)
S/R- (B) 7	14 S/R+ (B)
GND1 (B) 8	13 GND2 (B)
Out+ (B) 9	12 OUT- (B)
OFFSET- (B) 10	11 Vbridge (B)

Die A

Die B

• **Magnetômetro de 2 eixos HMC1002:**

(http://www.honeywell.com)
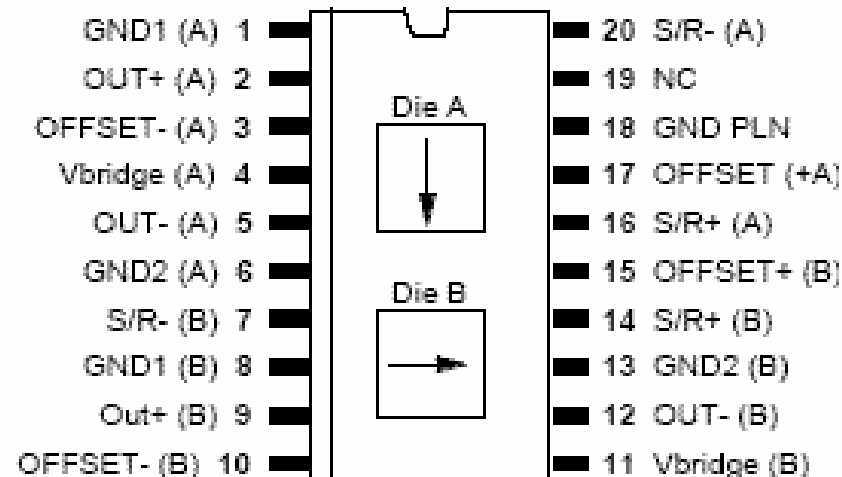
Figure 1–Conventional vs. Magnetic Sensing

Magnetômetro de 2 eixos HMC1002:

Classificação de veículos;

Direção e Presença de veículos;

Assinatura de veículos.

MTS300/MTS310
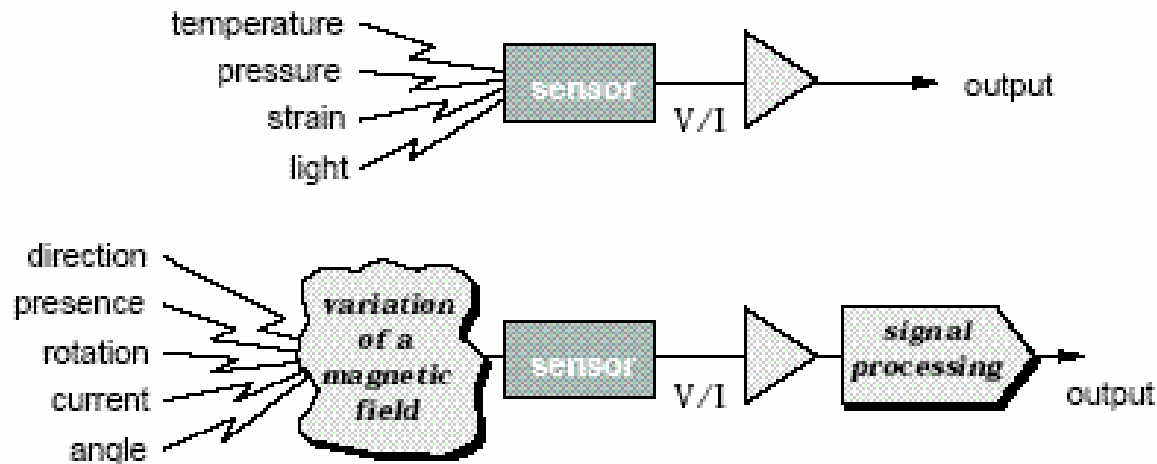
• **Microfone da Panasonic WM-62A**

Specifications	WM-62A/62C/62CC/62K/62B
Sensitivity:	—45±4dB (0dB=1V/Pa, 1kHz)
Impedance:	Less than 2.2kΩ
Directivity:	Omnidirectional
Frequency:	20-16,000Hz
Max. operation voltage:	10V
Standard operation voltage:	2V
Current consumption:	Max. 0.5mA
Sensitivity reduction:	Within —3dB at 1.5V
S/N ratio:	More than 58dB

MTS300/MTS310

Microfone da Panasonic WM-62A

- Detector de tom: LM567 (National);

- Sounder: ressonador piezoelétrico em 4 kHz (PS14T40A da Sirius)

MTS300/MTS310

Table 3-3. *Control Settings for the Sounder and Sensors*

Sensor/Actuator	Control Signal
Sounder	PW2
Microphone	PW3
Accelerometer	PW4
Magnetometer	PW5
Temperature (RT2)	INT2
Photocell (R2)	INT1

◀ **NOTE:** Only one of the INT1 and INT2 signals should be activated at a time. See Section 3.3

Leadtek® GPS-9546
Module
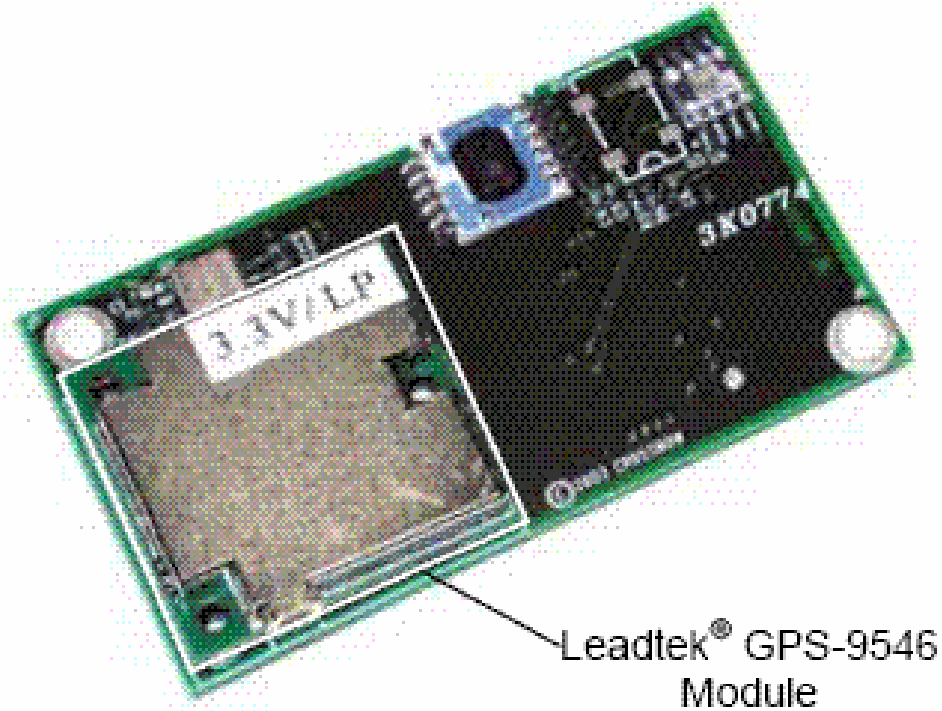
•A umidade não é nada mais que o vapor de água presente no ar;

•A umidade Relativa é a quantidade de vapor d´água presente no ar a uma dada temperatura respeitando a quantidade máxima de vapor d´água que o ar pode conter naquela temperatura quando saturada.

Sensor de Temperatura e Umidade Relativa

Módulo SHT11 da Sensirion (http://www.sensirion.com);

ADC de 14 bits interno;

Ultra Low Power.

Parameter	Conditions	Min.	Typ.	Max.	Units
Power supply DC		2.4	5	5.5	V
Supply current	measuring		550		μA
	average	2[2]	28[3]		μA
	sleep		0.3	1	μA

Table 4-1. *Summary of the Sensirion® SHT11's Specifications*

Sensor Type	Sensirion SHT11	
Channels	Humidity	Temperature
Range	0 to 100%	-40°C to 80°C
Accuracy	± 3.5% RH (typical)	± 2°C
Operating Range	3.6 to 2.4 volts	
Interface	Digital interface	

Block Diagram
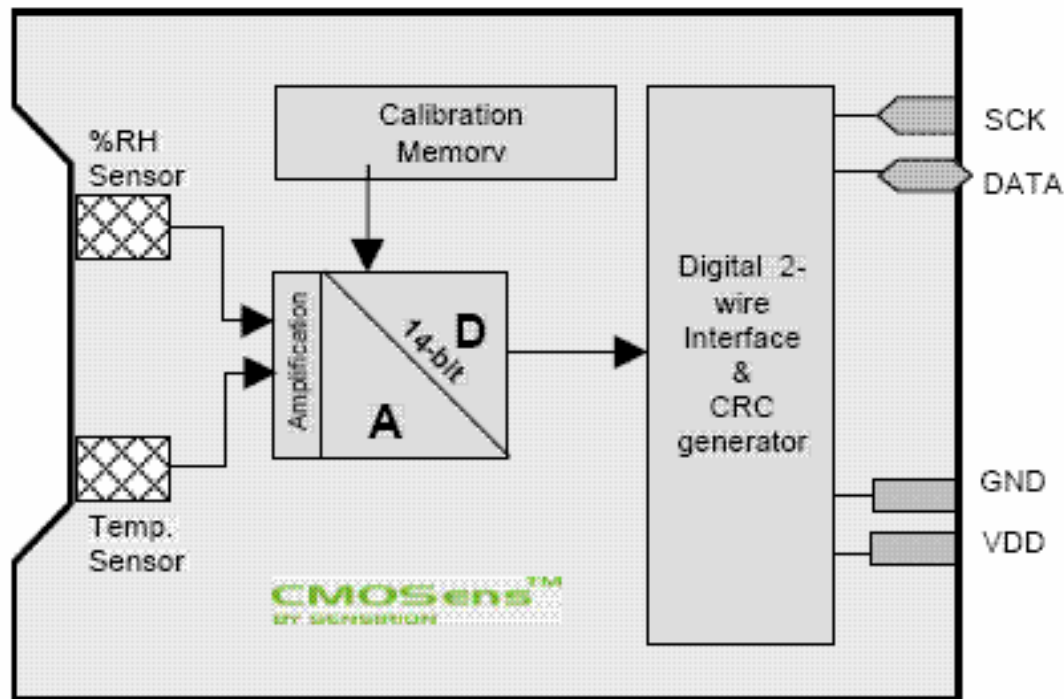
Pressão Barométrica e Temperatura

<u>**PRESSÃO BAROMÉTRICA**</u> **- Pressão exercida pela atmosfera sobre um determinado ponto. Sua medida pode ser expressa em milibares, ou em polegadas ou milímetros de mercúrio (Hg). Também conhecida como pressão atmosférica**

Pressão Barométrica e Temperatura

Table 4-2. *Summary of the Intersema® MS55ER's Specifications*

Sensor Type	Intersema MS5534
Channels	Pressure and Temperature
Range	Pressure: 300 to 110 mbar Temperature: -10°C to 60°C
Accuracy	Pressure: ± 3.5% Temperature: ± 2°C
Operating Range	3.6 to 2.2 volts
Interface	Digital interface

Pressão Barométrica e Temperatura

(T=25℃, VDD=3.0V unless noted otherwise)

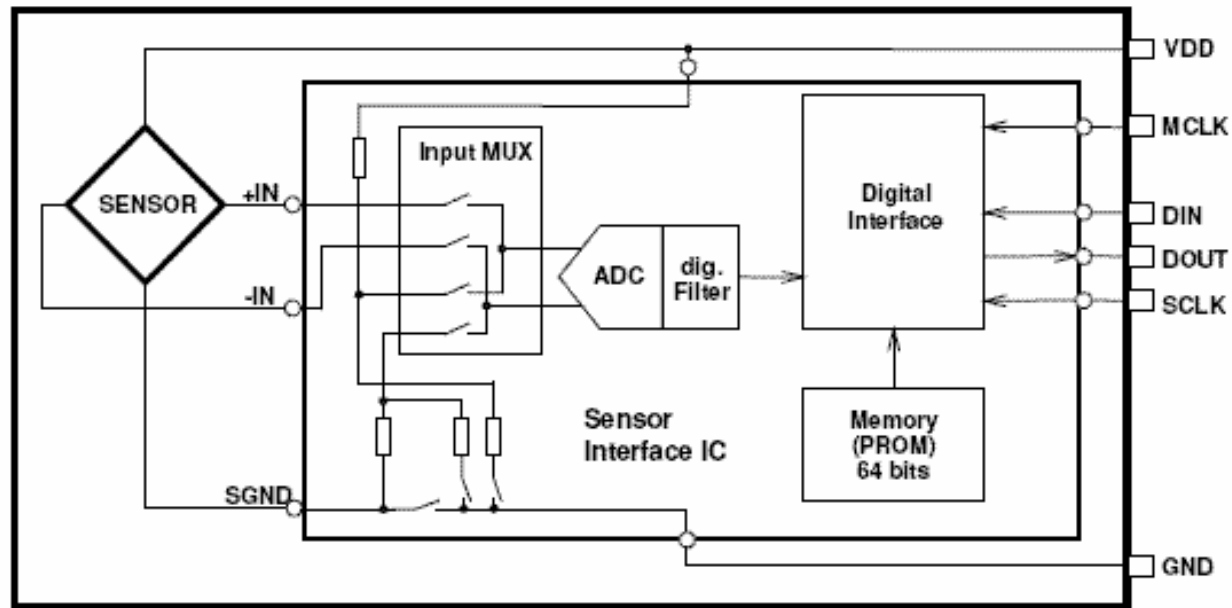| Parameter	Symbol	Conditions	Min.	Typ.	Max	Unit
Supply Voltage	V_{DD}		2.2	3.0	3.6	V
Supply Current, average (1) during conversion (2) standby (no conversion)	I_{avg} I_{SC} I_{ss}	V_{DD} = 3.0 V		5 1	3.5	μA mA μA
Current consumption into MCLK (3)		MCLK=32768Hz			0.5	μA

Pressão Barométrica e Temperatura

Fig.: 1 Block Diagram 5534

Sensor de Luz

Table 4-3. *Summary of TAOS TSL2550's Specifications*

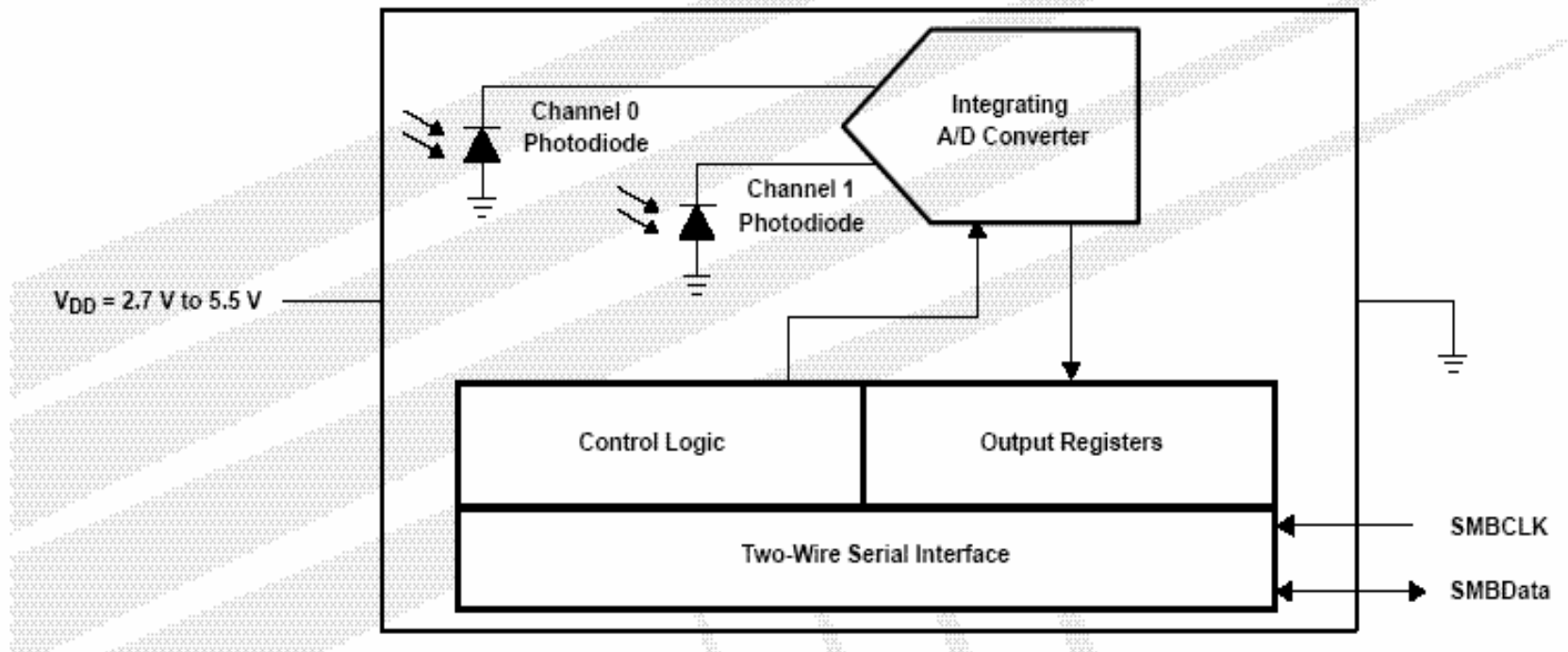| Sensor Type	Taos TSL2550
Channels	Light
Range	400 – 1000 nm
Operating Range	3.6 to 2.7 volts
Interface	Digital interface

Sensor de Luz

Functional Block Diagram

MTS400/MTS420

Sensor de Luz

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{OL}	SMBus output low voltage	I_O = 50 µA		0.01		V
		I_O = 4 mA			0.4	
I_{DD}	Supply current	Active, VSMBCLK and VSMDATA = V_{DD}, V_{DD} = 3.3 V ± 5%		0.35	0.6	mA
		Power down, VSMBCLK and VSMDATA = V_{DD}, V_{DD} = 3.3 V ± 5%			10	µA
I_{IH}	High level input current	VI = V_{DD}			5	µA
I_{IL}	Low level input current	VI = 0			−5	µA

Acelerômetro de 2 eixos

Table 4-4. *Summary of the ADXL202JE's Specifications.*

Sensor Type	Analog Devices ADXL202JE
Channels	X (ADC1), Y (ADC2)
Range	±2 G (1 G = 9.81 m/s^2)
Sensitivity	167 mV/G, ±17 %
Resolution	2 mG (0.002 G) RMS
Offset	VBATTERY/2 ±0.4 V
Operating Range	**3.6 to 3.0 V**
Interface	Analog interface

MTS400/MTS420

Módulo GPS

Table 4-5. *Summary of the SiRFstarIle LP's (GPS 9546) Specifications.*

GPS Chipset	SiRFstarIle LP
Antenna	External active antenna, power supplied by GPS module.
Channels	12
Meters	10 m, 2D
Start Time (sec)	45 Cold; 38 Warm; 8 Hot
Reacquisition Time	0.1 sec (typical, w/o dense foliage)
Protocol	NEMA-0183 and SIRF binary protocol
Current	60 mA at 3.3 V
Interface	Serial interface

MTS400/MTS420

Módulo GPS

Power

Main power input	3.3 ± 5% VDC input.
Power consumption	215 mW (continuous mode)
Supply Current	65 mA

Conclusões

- **Projeto de um magnetômetro de 3 eixos para viabilizar a assinatura de veículos;**

- **Implementar o circuito de recuperação automática de saturação na MTS310;**

- **Avaliar a viabilidade técnica e econômica em aquisições de novas placas sensoras (MTS).**

Referências Bibliográficas

[1] http://www.xbow.com/;

[2] http://www.clairex.com/;

[3] http://www.sensirion.com/;

[4] http://www.ysi.com/index.html;

[5] http://www.analog.com/;

[6] http://www.magneticsensors.com;

[7] http://www.national.com/;

[8] http://www.intersema.ch/;

[9] http://www.leadtek.com/;

[10] http://www.taosinc.com/