



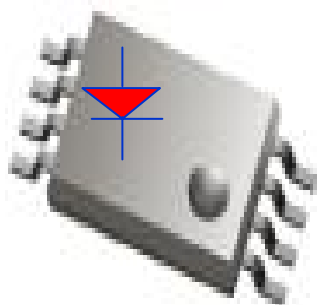
# **I2C 2005-1 Demonstration Board Temperature Sensors**

Oct, 2006

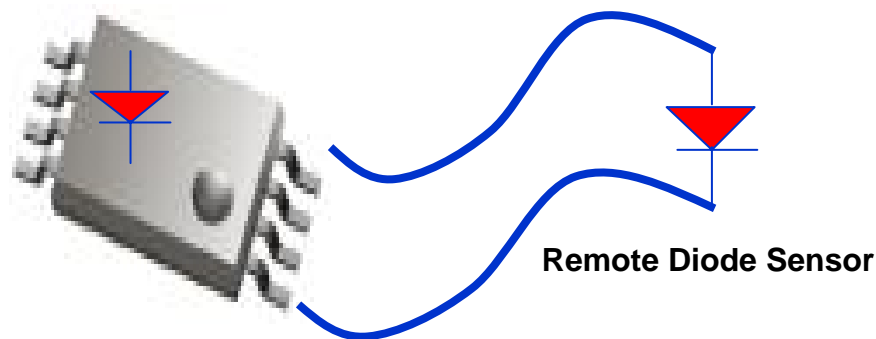


# Local versus Remote Temperature Sensors

Local Temperature Sensor  
Senses own die temperature



Local & Remote Temperature Sensor  
Senses own die temperature **AND**  
that of the remote diode sensor



Part#	Accuracy	SMBUS TIMEOUT
LM75A	$\pm 2\text{ }^{\circ}\text{C}$	NO
SE95	$\pm 1\text{ }^{\circ}\text{C}$	NO
SE98	$\pm 2\text{ }^{\circ}\text{C}$	YES

Part#	Local Sensor Accuracy	Remote Sensor Accuracy
NE1617A	$\pm 2\text{ }^{\circ}\text{C}$	$\pm 3\text{ }^{\circ}\text{C}$
NE1619*	$\pm 3\text{ }^{\circ}\text{C}$	$\pm 5\text{ }^{\circ}\text{C}$
SA56004	$\pm 2\text{ }^{\circ}\text{C}$	$\pm 1\text{ }^{\circ}\text{C}$

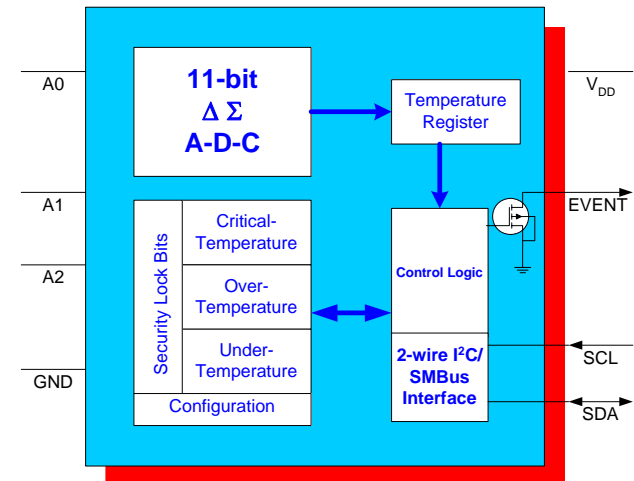
Note: \* with voltage monitors

# SE98 Local Temperature Sensor

- ▶ Local temperature sensor compliant to JEDEC JC42.4
- ▶ SE98 accuracy of  $\pm 2\text{ }^{\circ}\text{C}$  (75 to 90  $^{\circ}\text{C}$ )
- ▶ 11-bit (0.125  $^{\circ}\text{C}$ ) resolution
- ▶ 8 Hz minimum conversion rate
- ▶ 0  $^{\circ}\text{C}$ , 1.5  $^{\circ}\text{C}$ , 3  $^{\circ}\text{C}$ , 6  $^{\circ}\text{C}$  programmable hysteresis threshold
- ▶ EVENT# output associated with 3 alarms: upper, lower and critical
- ▶ Security lock bit for data protection
- ▶ Operating voltage range from 3.0 V to 3.6 V
- ▶ Maximum operating current: 250  $\mu\text{A}$
- ▶ 2-wire SMBus or I<sup>2</sup>C-bus standard/fast mode compatible
- ▶ Programmable SMBus Alert Response and TIMEOUT
- ▶ Operating temperature range from -20  $^{\circ}\text{C}$  to +125  $^{\circ}\text{C}$
- ▶ 3 programmable I<sup>2</sup>C address pins: 0011 [A2 A1 A0]
- ▶ Offered in TSSOP8 and HVSON8\* package

**With SMBus TIMEOUT  
& Security lock bits**

**Block Diagram**

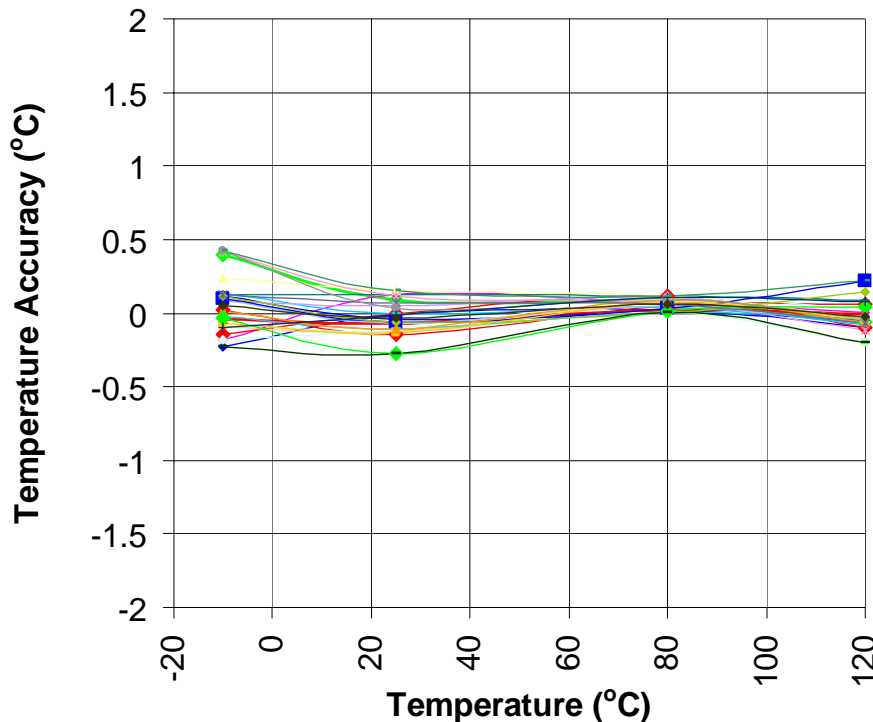


\*Note: 3mm x 3mm

# Excellent Accuracy Characteristic

## SE98 Temperature Accuracy

25 Devices Tested @V<sub>CC</sub> = 3.3 V



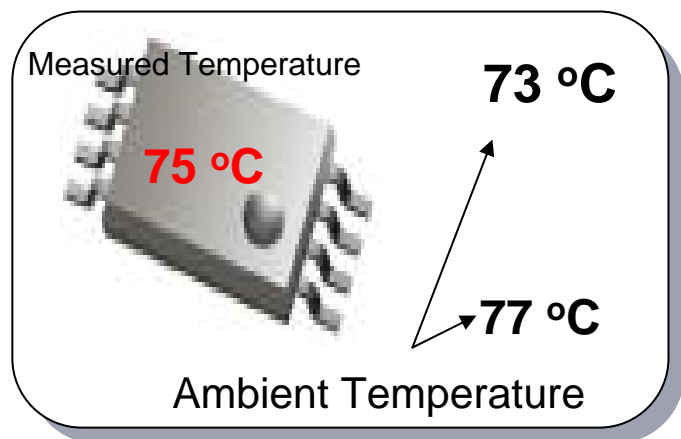
From 25 Devices

- Temperature accuracy is well controlled over the entire temperature range
- Lot to lot variation may shift the accuracy up or down

# Temperature Accuracy Versus Resolution

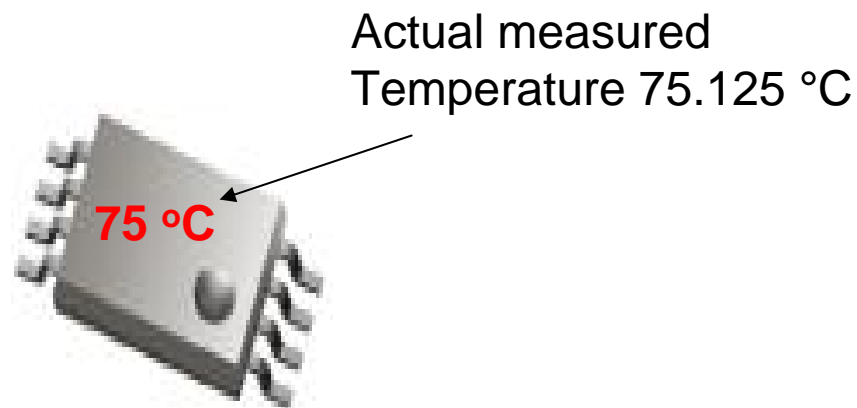
## Temperature Accuracy

- ▶ Accuracy and error are used synonymously, and is the measure of how precisely the temperature sensor reading matches the ambient temperature
- ▶ Example:  $\pm 2$  °C accuracy

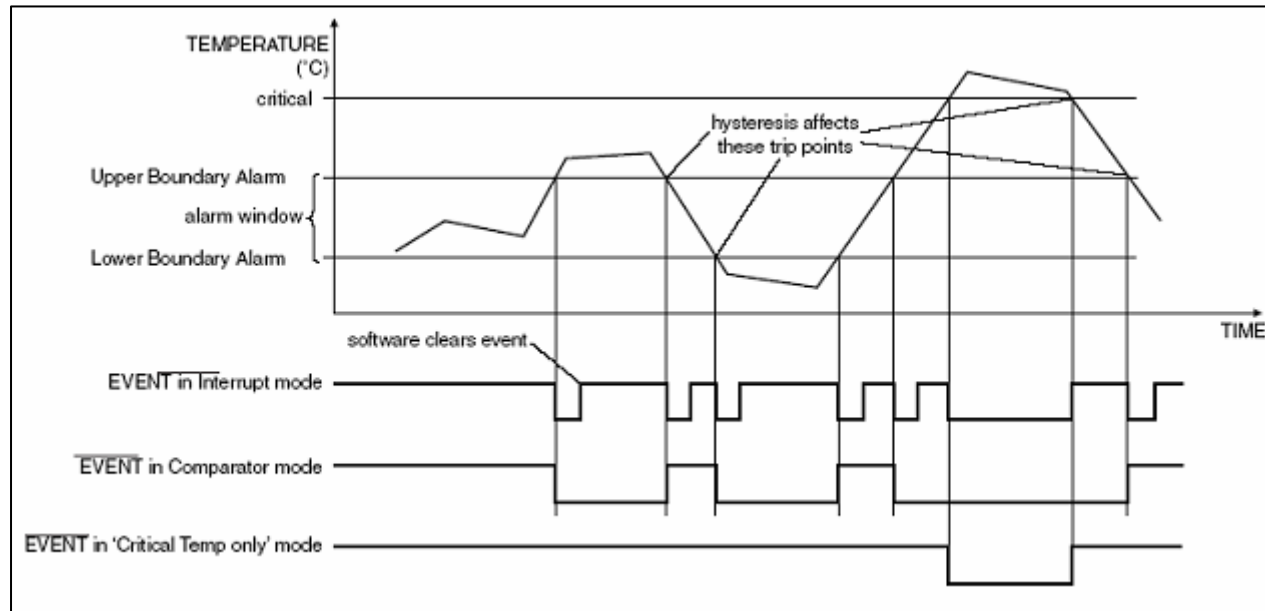


## Temperature Resolution

- ▶ Is the measure of temperature sensor's smallest measuring step
- ▶ Example of 0.125 °C resolution



# Comparator versus Interrupt Mode



Comparator mode:

EVENT output is cleared by itself once the temperature drops below the setpoints

Interrupt mode:

EVENT output is latched and only cleared by writing to the clear event bit

# Configuration Register

## Critical Lock Bit

0: alarm register not locked, register value can be changed

1: alarm register locked, register value cannot be changed

## ALARM Lock Bit

0: Alarm not locked, upper and lower alarm can be modified

1: Alarm locked, upper and lower alarm cannot be modified

## Clear EVENT flag

0: no effect

1: clear the event flag in interrupt mode

## Hysteresis for alarm

00: hysteresis disabled

01: hysteresis = 1.5 °C

10: hysteresis = 3 °C

11: hysteresis = 6 °C

0: Temp sensor shutdown mode

1: Normal mode

## Register is 2 Byte

Bit	15	14	13	12	11	10	9	8
Symbol			RFU			HEN		SHMD
Reset	0	0	0	0	0	0	0	0
Access	R	R	R	R	R	R/W	R/W	R/W

Bit	7	6	5	4	3	2	1	0
Symbol	CTLB	AWLB	CEVNT	ESTAT	EOCTL	CVO	EP	EMD
Reset	0	0	0	0	0	0	0	0
Access	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

## EVENT Status bit

0: not asserted

1: asserted

## EVENT output control bit

0: EVENT output disabled

1: EVENT output enabled

## Critical EVENT Only

0: Critical+Alarm

1: Critical

## EVENT Polarity

0: Active low

1: Active high

## EVENT Mode

0: Comparator mode

1: Interrupt mode

# SE98 Registers

Address (hex)	POR state (hex)	Register name
n/a	n/a	Pointer Register
00h	0015h/0017h	Capability Register (B-grade = 0017h, C-grade = 0015h)
01h	0000h	Configuration Register
02h	0000h	Upper Boundary Alarm Trip Register
03h	0000h	Lower Boundary Alarm Trip Register
04h	0000h	Critical Alarm Trip Register
05h	n/a	Temperature Register
06h	1131h	Manufacturer ID Register
07h	A100h	Device ID/Revision Register
08h to 21h	0000h	reserved registers
22h	0000h	SMBus Register
23h to FFh	0000h	reserved registers



# Temperature Data Register

Above Critical indicates whether the temperature exceeds the critical temperature

0: temp is below critical temperature

1: temp exceeds critical temperature

Above ALARM window indicates whether the temperature exceeds the alarm temperature

0: temperature is below the upper alarm

1: temperature exceeds the upper alarm

Below ALARM Window indicates whether the temperature falls below the lower alarm

0: temperature is above the lower alarm

1: temperature falls below the Lower ALARM

Sign bit

0: positive temperature

1: negative temperature

Register is 2 Byte

Bit	15	14	13	12	11	10	9	8
Symbol	ACT	AAW	BAW	SIGN	TEMP			
Reset	0	0	0	0	0	0	0	1
Access	R	R	R	R	R	R	R	R
Bit	7	6	5	4	3	2	1	0
Symbol	TEMP							RFU
Reset	1	0	0	1	0	0	1	0
Access	R	R	R	R	R	R	R	R

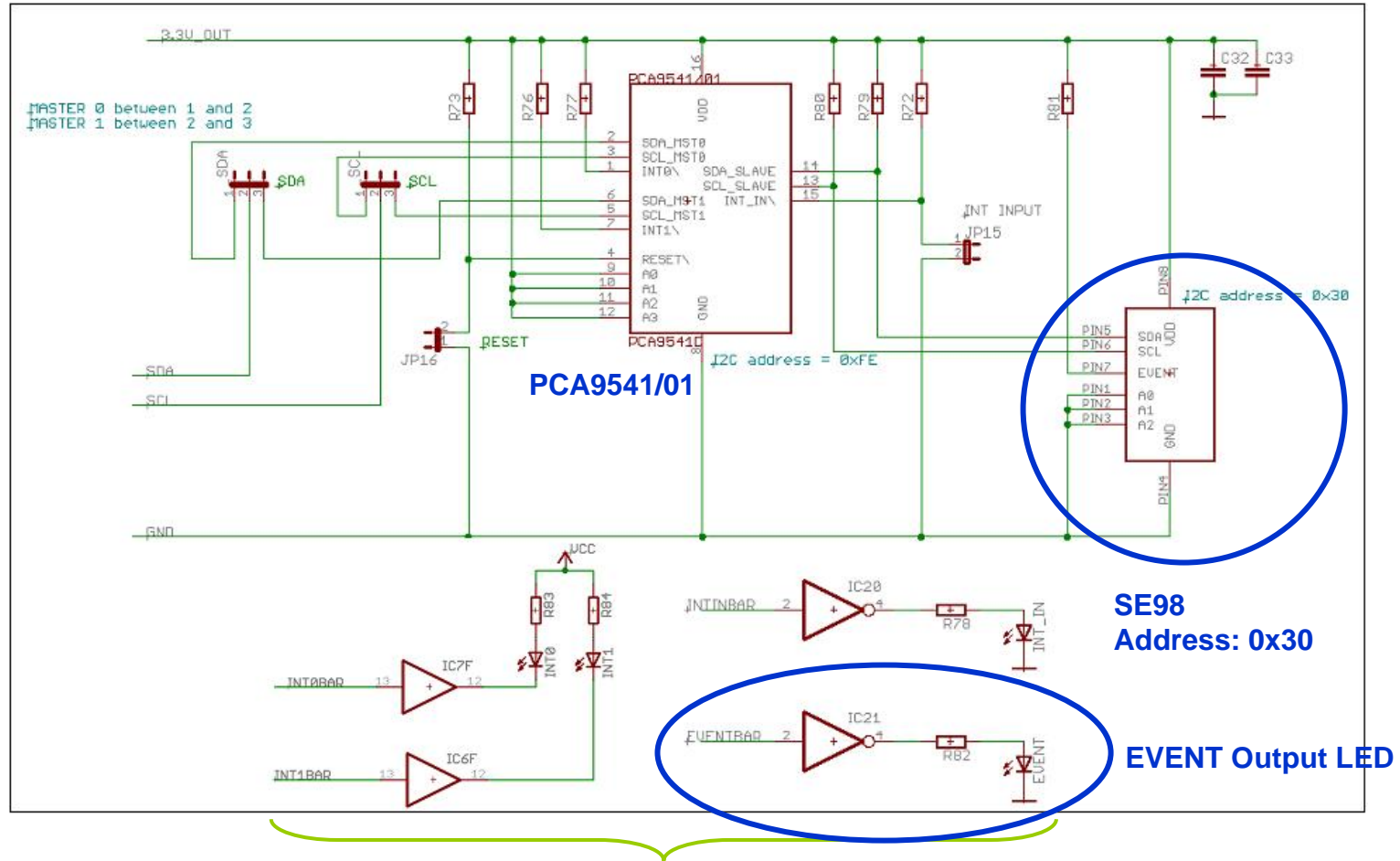
Integer

Decimal

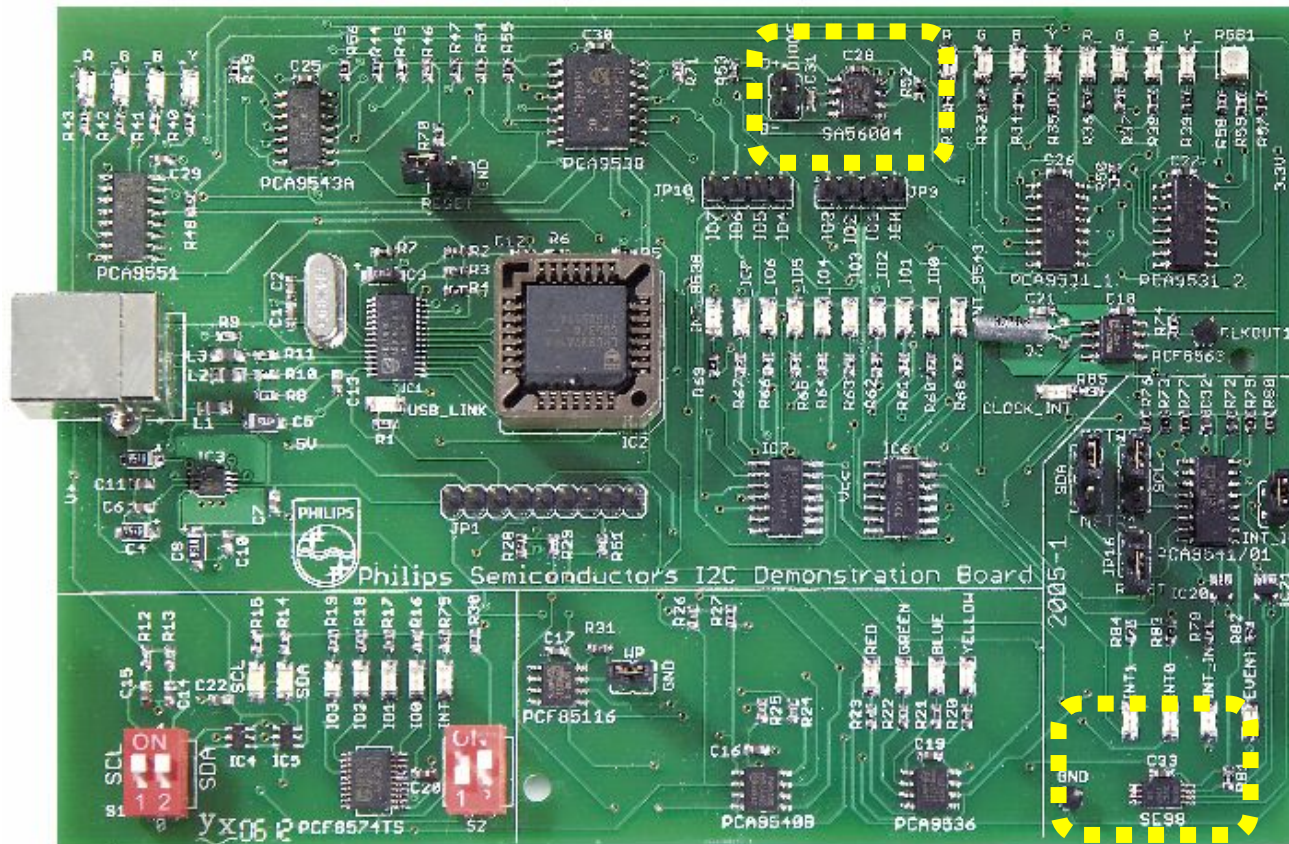
Reserved for future use

Temperature Value = 25.125 °C

# SE98 Training Board Schematic



# Training Board: Hardware Introduction



# SE98 Software GUI

Device → Thermal Management → SE98

Temperature Reading

Alarm Status bits

Cyclic Read

Device Address

Configuration & Status Registers

Auto write

Alarm setpoints

The screenshot displays the 'Win-I2CUSB Lite - [SE98 Temperature Sensor]' application window. The interface is divided into several sections:   
1. \*\*Device Address\*\*: A dropdown menu showing '0x30' with a note 'Address limited to 0x30 in Win-I2CUSB Lite'.   
2. \*\*Configuration=0x0000\*\*: A section with a 'Disable hysteresis' dropdown and a list of checkboxes for sensor and alarm settings.   
3. \*\*Temperature Register\*\*: Shows 'Temperature= 20.00°C' and 'Temperature Register=0x0000'. It includes checkboxes for 'ACT', 'AAW', and 'BAW', and buttons for 'Read' and 'Cyclic Read'.   
4. \*\*SMBus Register\*\*: Contains checkboxes for 'SMBus time-out enabled' and 'SMBus alert enabled', and buttons for 'Write' and 'Read'.   
5. \*\*Upper Boundary Alarm Trip (°C)\*\*: Shows '0.00 °C' and 'UBAT = 0x0000' with 'Write' and 'Read' buttons.   
6. \*\*Lower Boundary Alarm Trip (°C)\*\*: Shows '0.00 °C' and 'LBAT = 0x0000' with 'Write' and 'Read' buttons.   
7. \*\*Critical Alarm Trip (°C)\*\*: Shows '0.00 °C' and 'CAT = 0x0000' with 'Write' and 'Read' buttons.   
8. \*\*Capability=0xFFFF', 'Manufacturer ID=0xFFFF', and 'Device ID=0xFFFF'\*\*: Each has a 'Read' button.   
9. \*\*Automatic Write\*\*: A section with an 'Off' checkbox and 'Write All' and 'Read All' buttons.   
10. \*\*Status Bar\*\*: At the bottom, it shows 'Transmission successful', 'Hardware Detected', '3.3V On', '5.0V On', and '100 kHz'.



# SE98 Hands-On: Device Initialization

Set critical boundary alarm trip to 80 °C boundary registers

Set hysteresis to  
1.5 °C

Set upper boundary alarm trip to 27 °C

Enable  
/EVENT  
output

Transmission  
Successful  
Indicates SE98  
responding

Win-I2C USB Lite - [SE98 Temperature Sensor]

File Device Options Window Help

Device Address: 0x30  
Address limited to 0x30 in Win-I2C USB Lite

Configuration=0x0208

Enable hysteresis at 1.5°C

☐ Temp sensor on  
☐ Crit. trip register not locked  
☐ Alarm Window not locked  
☐ Event not cleared  
☐ EVENT not asserted  
☒ EVENT output enabled  
☐ Alarm or Critical Event  
☐ EVENT output active low  
☐ Comparator Mode

Write Read

Temperature Register  
Temperature=24.625°C  
Temperature Register=0x018A  
☐ ACT ☐ AAW ☐ BAW  
Read Cyclic Read

Upper Boundary Alarm Trip (°C)  
27.00°C  
UBAT = 0x01B0  
Write Read

Lower Boundary Alarm Trip (°C)  
0.00°C  
LBAT = 0x0000  
Write Read

Critical Alarm Trip (°C)  
80.00°C  
CAT = 0x0500  
Write Read

SMBus Register=0x0000  
☐ SMBus time-out enabled  
☐ SMBus alert enabled  
Write Read

Capability=0x0015  
Read

Manufacturer ID=0x1131  
Read

Device ID=0xA101  
Read

Automatic Write  
☒ On

Write All Read All

Transmission successful Hardware Detected 3.3V On 5.0V On 100 kHz

Autowrite ON

# SE98 Hands-on (2) – EVENT output in Comparator versus Interrupt Mode

1. Visually check EVENT LED – it should be OFF
2. Click on the “Cyclic read” for continuous temperature update
3. Heat up or place your finger over the SE98 for a few minutes for temperature to exceed 28 °C, the EVENT LED is ON
4. Cool down or remove your finger from the SE98 and wait for a 1 minute or 2 until the temperature drops below 28 °C
  - What happens to the EVENT LED now?
    - EVENT LED is OFF
5. Change the EVENT output to Interrupt mode and repeat steps 1-4.
  - What happens to the EVENT LED now?
    - EVENT LED is still ON
6. Clear the EVENT bit.
  - EVENT LED is OFF

## Conclusion?

- Comparator mode, the EVENT output de-asserted and LED is OFF when temperature falls within the ALARM window
- Interrupt mode, the EVENT output stays asserted and LED is ON even after the temperature drops back within the ALARM window. The output is cleared by writing to the “event clear bit”

# SE98 Hands-on (cont.) – Security lock bits

1. Read the upper, lower and critical alarm boundary trips registers.  
What are their values?  
Upper = 28 °C; Lower = 0 °C; Critical = 85 °C
2. Change the upper, lower and critical alarm boundary trip to 35 °C, -20°C, and 125 °C and read them back. What are their values?  
Upper = 35 °C  
Lower = - 20 °C  
Critical = 125 °C
3. Check the “lock the Critical” and “lock alarm window” bits
4. Change the upper, lower, and critical alarm boundary trips to 28 °C, 0 °C, and 85 °C, and read them back. What are their values? No change
5. Remove the power will reset remove the lock feature

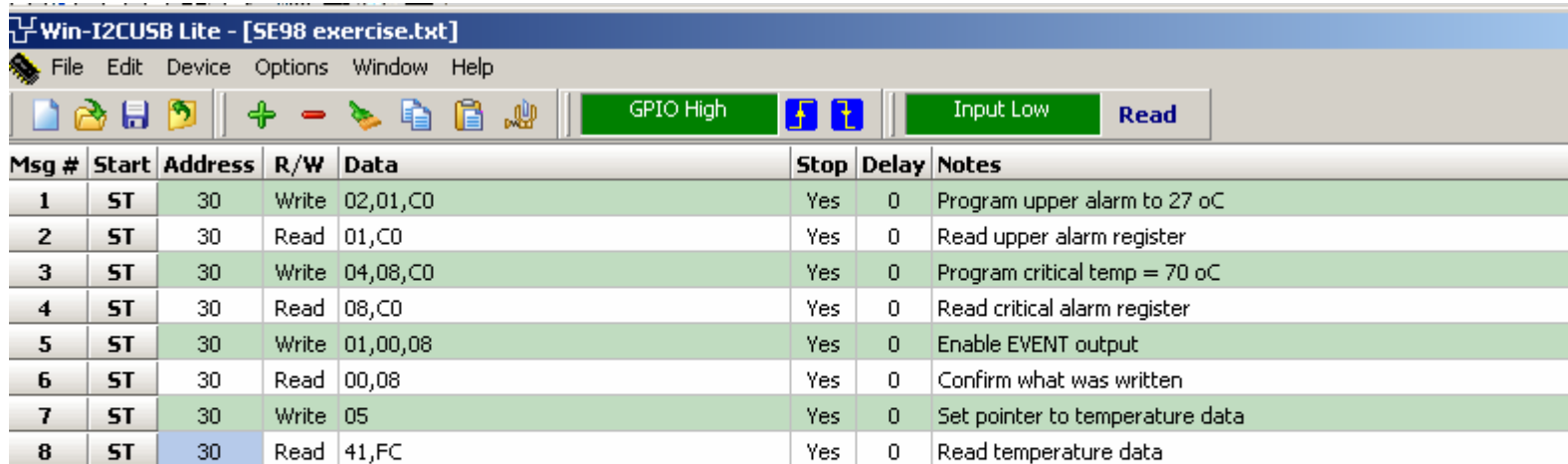
Conclusion: lock bit protects alarm setpoint values. Once lock bit is written, you can only clear it by powering off the SE98.

# Expert Mode Exercise

- ▶ Power off and on the board
- ▶ Use the Expert Mode, write and verify the following codes:
  1. Set the upper alarm to 27 °C
  2. Confirm what you wrote is correct
  3. Set the critical temperature to 70 °C
  4. Confirm what you wrote is correct
  5. Write to configuration register to enable the EVENT output
  6. Read what you've just wrote
  7. Heat up SE98 and read the configuration register
  8. Read the temperature value



# Solution



The screenshot shows the Win-I2CUSB Lite application window titled "Win-I2CUSB Lite - [SE98 exercise.txt]". The menu bar includes File, Edit, Device, Options, Window, and Help. The toolbar contains icons for file operations and I2C control. On the right, there are buttons for "GPIO High", "Input Low", and "Read". Below the toolbar is a table with 8 rows of I2C messages.

Msg #	Start	Address	R/W	Data	Stop	Delay	Notes
1	ST	30	Write	02,01,C0	Yes	0	Program upper alarm to 27 oC
2	ST	30	Read	01,C0	Yes	0	Read upper alarm register
3	ST	30	Write	04,08,C0	Yes	0	Program critical temp = 70 oC
4	ST	30	Read	08,C0	Yes	0	Read critical alarm register
5	ST	30	Write	01,00,08	Yes	0	Enable EVENT output
6	ST	30	Read	00,08	Yes	0	Confirm what was written
7	ST	30	Write	05	Yes	0	Set pointer to temperature data
8	ST	30	Read	41,FC	Yes	0	Read temperature data

Win-I2CUSB Lite limitations:

Addresses limited to those on Philips I2C board

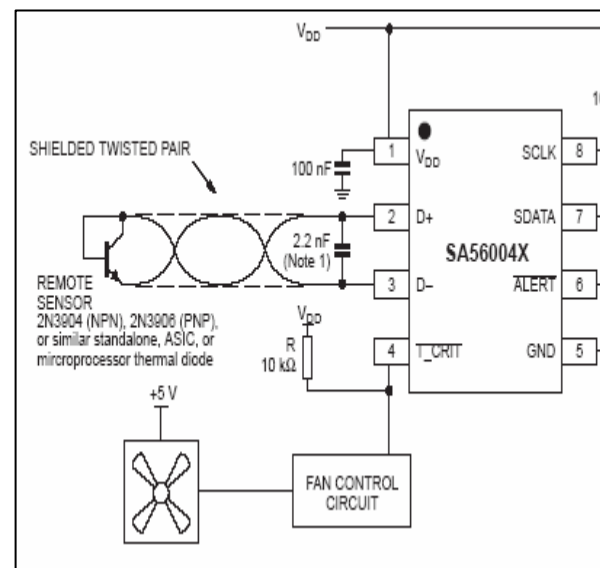
8 messages or rows

8 data bytes per message (128 bytes in full version of Win-I2CUSB)

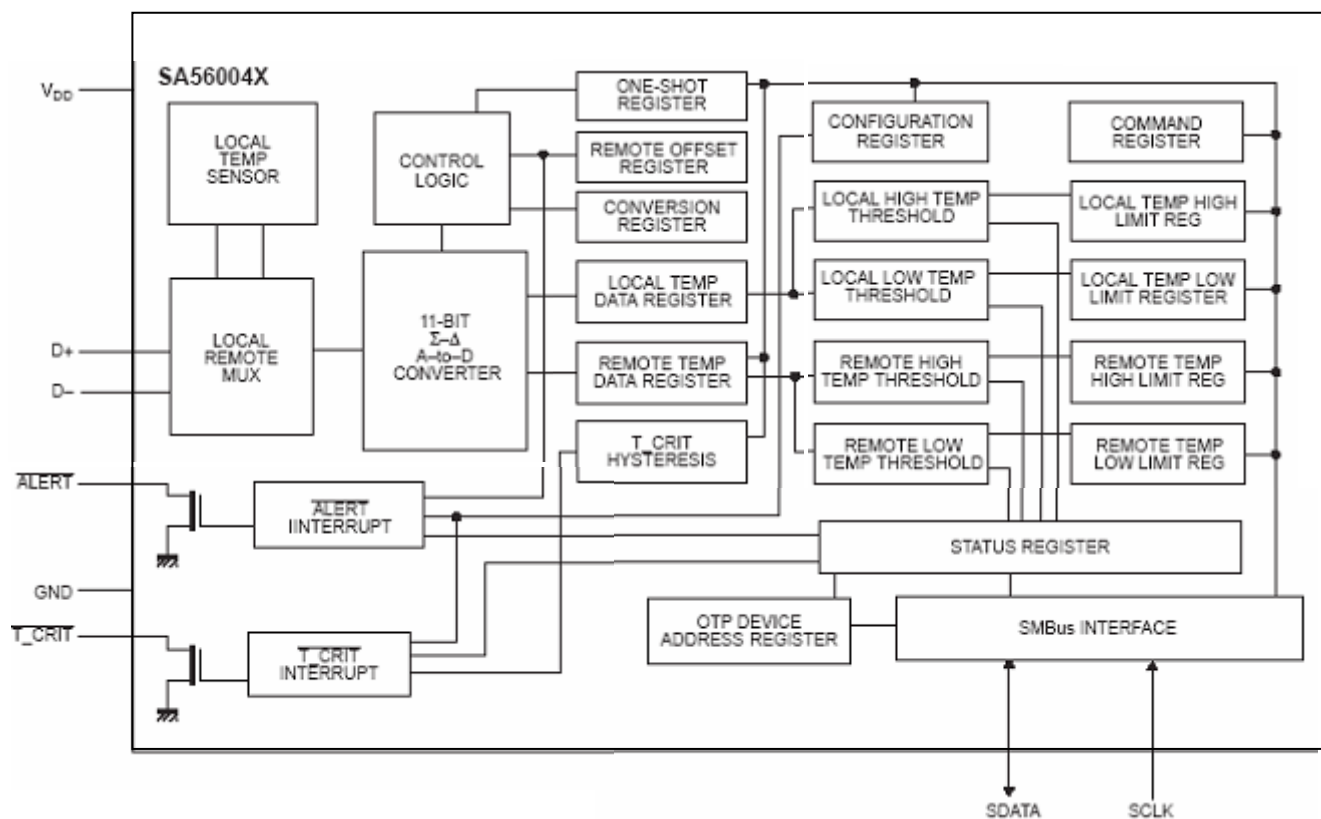
# SA56004 Local & Remote Temp Sensor

- ▶ Monitors remote and local temperatures
- ▶ Accuracy of  $\pm 1$  °C remote temperature sensing
- ▶ 11-bit ADC or 0.125 °C resolution
- ▶ Offset registers for the remote sensing accuracy
- ▶ ALERT#/T\_CRIT# output for interrupt/fan control (on/off)
- ▶ 2-wire SMBus, or I<sup>2</sup>C standard/fast mode compatible
- ▶ Supports SMBus ALERT Response and TIMEOUT
- ▶ One-shot control for power saving
- ▶ Programmable Fault Queue
- ▶ Diode fault detection
- ▶ Up to 8 different device addresses
- ▶ Offered in TSSOP(MSOP)8 and SO8 packages

**$\pm 1$  °C Accuracy  
With fan control**



# SA56004 Block Diagram



# SA56004 Registers

REGISTER NAME	COMMAND BYTE		POR STATE	FUNCTION	BITS	ACCESSIBILITY
	READ ADDRESS	WRITE ADDRESS				
LTHB	00h	NA	0000 0000	Local Temperature HIGH Byte	8	R
RTHB	01h	NA	0000 0000	Remote Temperature HIGH Byte	8	R
SR	02h	NA	0000 0000	Status Register	8	R
CON	03h	09h	0000 0000	Configuration Register	8	R/W
CR	04h	0Ah	1000	Conversion Rate	4	R/W
LHS	05h	0Bh	0100 0110	Local HIGH Setpoint	8	R/W
LLS	06h	0Ch	0000 0000	Local LOW Setpoint	8	R/W
RHSHB	07h	0Dh	0100 0110	Remote HIGH Setpoint High Byte	8	R/W
RLSHB	08h	0Eh	0000 0000	Remote LOW Setpoint High Byte	8	R/W
One Shot	NA	0Fh		Writing register initiate a one shot conversion	0	W
RTLB	10h	NA	0000 00	Remote Temperature LOW Byte	6(MSBs)	R
RTOHB	11h	11h	0000 0000	Remote Temperature Offset High Byte	8	R/W
RTOLB	12h	12h	000	Remote Temperature Offset Low Byte	3(MSBs)	R/W
RHSLB	13h	13h	000	Remote HIGH Setpoint Low Byte	3(MSBs)	R/W
RLSLB	14h	14h	000	Remote LOW Setpoint Low Byte	3(MSBs)	R/W
RCS	19h	19h	0101 0101	Remote T_CRIT Setpoint	8	R/W
LCS	20h	20h	0101 0101	RLocal T_CRIT Setpoint	8	R/W
TH	21h	21h	0 1010	T_CRIT Hysteresis	5	R/W
LTLB	22h	NA	0000 0000	Local Temperature Low Byte	3(MSBs)	R
AM	BFh	BFh	0	Alert Mode	1	R/W
RMD	FEh	NA	1010 0001	Read Manufacturer's ID	8	R
RDR	FFh	NA	0000 0000	Read Stepping or Die Revision	8	R

# Configuration and Status Registers

## Configuration Register (1 Byte)

Write addr = 09h; Read addr = 03h

Bit	Name/Function	POR state
7 (MSB)	ALERT mask The ALERT interrupt is enabled when this bit is LOW. The ALERT interrupt is disabled (masked) when this bit is HIGH.	0
6	RUN/STOP Standby or run mode control; Running mode is enabled when this bit is LOW. The SA56004X is in standby mode when this bit is HIGH.	0
5	Not defined. Defaults to "0" (zero).	0
4	Remote T_CRIT mask The T_CRIT output will be activated by a remote temperature that exceeds the remote T_CRIT setpoint when this bit is LOW. The T_CRIT output will not be activated under this condition when this bit is HIGH.	0
3	Not defined. Defaults to "0" (zero).	0
2	Local T_CRIT mask The T_CRIT output will be activated by a local temperature that exceeds the local T_CRIT setpoint when this bit is LOW. The T_CRIT output will not be activated under this condition when this bit is HIGH.	0
1	Not defined. Defaults to "0" (zero).	0
0	Fault Queue A single remote temperature measurement outside the HIGH, LOW or T_CRIT setpoints will trigger an outside limit condition resulting in setting the status bits and associated output pins when this bit is LOW. Three consecutive measurements outside of one of these setpoints are required to trigger an outside of limit condition when this bit is HIGH.	0

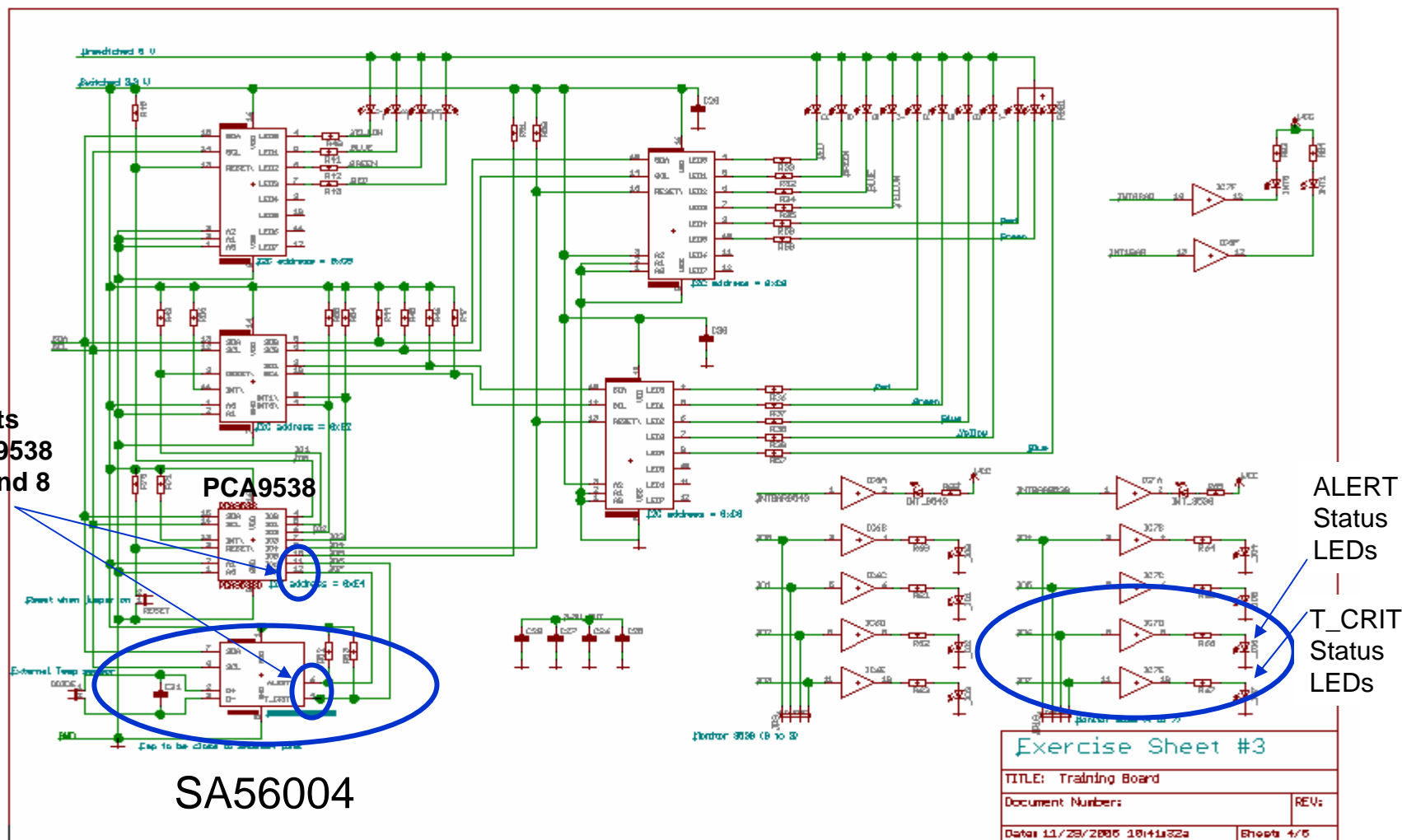
## Status Register (1Byte)

Read addr = 02h; Write addr = N/A

Bit	Name/Function	POR state
7	BUSY When '1' A/D is busy converting.	n/a
6	LHIGH When '1' indicates Local HIGH temperature alarm.	0
5	LLOW When '1' indicates a Local LOW temperature alarm.	0
4	RHIGH When '1' indicates a Remote Diode HIGH temperature alarm.	0
3	RLOW When '1' indicates a Remote Diode LOW temperature alarm.	0
2	OPEN When '1' indicates a Remote Diode disconnect.	0
1	RCRIT When '1' indicates a Remote Diode Critical Temperature alarm.	0
0	LCRIT When '1' indicates a Local Critical Temperature alarm.	0

# SA56004 Training Board Schematic

ALERT  
T\_CRIT  
Connects  
To PCA9538  
Port 7 and 8



# SA56004 Software GUI

Device Address 0x98

Status Reg

Config Reg

Conversion rate

Autowrite

Local Temperature

Remote temperature

Temperature HIGH/LOW Limits

Critical Temperature Limit

Offset reg

Cyclic read

1-shot

Win-I2CUSB Lite - [SA56004A Temperature Sensor]

File Device Options Window Help

Device Address: 0x98 (Address limited to 0x98 in Win-I2CUSB Lite)

Status Register=0x00

- ☐ ADC not busy
- ☐ Int high temp not tripped
- ☐ Int low temp not tripped
- ☐ Ext high temp not tripped
- ☐ Ext low temp not tripped
- ☐ External diode not open
- ☐ Remote Not Critical Temp
- ☐ Local Not Critical Temp

Configuration = 0x00

- ☐ Alert interrupt enabled
- ☐ Running mode
- ☐ Remote T(crit) Enabled
- ☐ Local T(crit) Enabled
- ☐ Fault Queue: single

Conversion Rate (CR): 16 Hz

Automatic Write: Off

Local Temperature (°C): Local Temperature=70°C, LTHB=0x00, LTLB=0x00

Remote Temperature (°C): Remote Temperature=0°C, RTHB=0x00, RTLB=0x00

Local Temp Limits (°C): Local HIGH Setpoint=70°C, LHS=0x46, Local LOW Setpoint=0°C, LLS=0x00

Remote Temp Limits (°C): Remote HIGH Setpoint=70.000°C, RHSB=0x46, RHSB=0x00, Remote LOW Setpoint=0.000°C, RLSB=0x00, RLSB=0x00

Local T\_CRIT (°C): T\_CRIT=85°C, LCS=0x55

T\_CRIT Hysteresis: Hysteresis=10°C, TH=0x0A

Remote T\_CRIT (°C): T\_CRIT=85°C, RCS=0x55

Remote Temperature Offset (°C): Remote Temp Offset=0.000°C, RTOHB=0x00, RTOLB=0x00

Read ID: RMID = 0xXX, RDR = 0xXX

One Shot: ☐ Interrupt Mode

Write All: Cyclic Read

Hardware Not Detected | 3.3V off | 5.0V off

# SA56004 Exercise

1. Select “cyclic read”
2. Read the status and configuration registers. What are the bits?
  - all bits should be clear
3. Set the remote high set-point register to 50 °C,
4. Set remote low set-point to 10 °C, and remote T\_CRIT to 60 °C
5. Place the remote sensor diode in the hot water and record the remote temperature reading
6. Read the status register. Which bit is asserted?
  - External high temp bit is set
7. Place the remote sensor diode in a cup of ice water for 2 minutes or more
8. Read the status register. Which bit(s) is asserted?
  - External low temp bit is set
9. Read the local temperature value
  - Room temperature
10. Put the device in standby mode, place your finger over the SA56004, What happens to the local and remote temperature reading?
  - No change
11. Keep the finger on the SA56004 and click on the one-shot push button. What happens to the local and remote temperature reading?
  - Updated to your body temperature



# Expert Mode Exercise

- ▶ Power on and off the board
- ▶ Use the expert mode, write and verify the following codes:
  1. Program SA56004 to standby (STOP) mode in the configuration register
  2. Program the pointer to the remote temperature register high byte
  3. Read the remote temperature data register high byte
  4. Program the pointer to the remote temperature register low byte
  5. Read the remote temperature data register low byte
  6. Issue a one-shot command
  7. Read the remote temperature data high and low byte (repeat steps 3 and 5)

# Solution

Win-I2CUSB Lite - [56004 exercise.txt]									
File Edit Device Options Window Help									
GPIO High Input Low Read									
Msg #	Start	Address	R/W	Data	Stop	Delay	Notes		
1	ST	98	Write	09,40	Yes	0	Read configuration register		
2	ST	98	Write	01	Yes	0	Program pointer to remote temp sensor high byte		
3	ST	98	Read	19	Yes	0	Read high byte		
4	ST	98	Write	10	Yes	0	Remote temperature low byte		
5	ST	98	Read	C0	Yes	0	Read remote temperature low byte		
6	ST	98	Write	0F,00	Yes	0	Initiate one-shot command		

# Temp Sensors Selection Table

	Part#	Temperature range	Accuracy		Resolution	Power Supply Range	Supply current	
			Local	Remote			Operating	Shutdown
Local	LM75A	-55 °C to 125°C	+2 °C	N/A	0.125 °C / LSB	2.7 V to 5.5 V	1 mA	3.8 µA
	SE95	-55 °C to 125°C	+1 °C	N/A	0.03125 °C / LSB	2.8 V to 5.5 V	1 mA	7.5 µA
	SE98	-20 °C to 125°C	+2 °C	N/A	0.125 °C / LSB	3.0 V to 3.6 V	100 µA	
Remote/Local	SA56004	-55 °C to 125°C	+2 °C	+1 °C	0.125 °C / LSB	3.0 V to 3.6 V	500 µA	10 µA
	NE1617A	-55 °C to 125°C	+2 °C	+3 °C	1 °C / LSB	3.0 V to 5.5 V	70 µA	3.5 µA
	NE1618	-55 °C to 125°C	+2 °C	+1 °C	0.125 °C / LSB	3.0 V to 3.6 V	80 µA	3 µA
Voltage Monitor	NE1619	-55 °C to 125°C	+5 °C	+3 °C	1 °C / LSB	2.8 V to 5.5 V	500 uA	100 µA

# Temperature Sensor Applications



## CONSUMER



## COMMUNICATION



## COMPUTING/STORAGE



PC



SO-DIMM



## INDUSTRIAL



Laptop



Server

