Microprocessor Programming And Interfacing

DESIGN PROJECT

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Based on problem number 10

Submitted By :

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PROBLEM STATEMENT AND SPECIFIC DETAILS :

System to be designed : Weather Monitoring Station

Description of the problem : This system monitors weather parameters such as: Air Temperature, Air-Humidity, barometric Pressure, wind speed and Displays the average over regular intervals of an hour on a LCD display. The Display is continuous. Update of the display is done once in an hour. Weather parameters are sensed at regular intervals of 2 minutes.

Display Format : **"Temperature – Value ^{0}C"** and so on. Other than the regular display, the user can request the display of the weather parameters to be updated at any point of time by pressing a push button key. The accuracy of the parameters monitored has to be up to two decimal points.

DESCRIPTION :

The analog input for the system is received from the sensors which are connected to an 8 bit parallel ADC (0808). These sensor modules generate analog voltages ~0-5V which is connected to the ADC, which in turn, generates an 8 bit value between 0 and 255.

There is an 8259 Programmable Interrupt controller device that accepts four interrupts from various sources, namely

- The timers
- An external button and
- An EOC interrupt from the ADC.

The IVT for the 8259 is stored in the ROM at a vector address of 80h onwards (corresponding to a memory address 80h*4=00200h). There are two timer IC's (8253) generating interrupts every 2 minutes and every one hour.

Every two minutes, an interrupt is generated and an ISR is invoked in which the ADC value is read and this digital data is stored in the RAM. It is as though an array of thirty elements is maintained for each sensor, where after the thirtieth reading of data, the next value is stored in the first position. Therefore, the past 30 readings are always maintained.

Every one hour, there is an interrupt generated that invokes an ISR that averages the values for the past hour.

For the first hour, averaging is done for only the number of values available. After averaging, the values are scaled according to the specifications of the sensors. This scaled and average value is displayed.

There is also an external button which on pressing, generates an interrupt which takes a reading and averages the past 30 readings (including the current reading i.e. the past hour). This displays value on the LCD as per the request of the external button.

SCALING :

The ADC used in the design produces a voltage between 0 and 255_d for the sensors. To scale it to the values for Pressure, Temperature and Humidity, we use a scaling function that employs the following formulae:

Pressure	: (0-2bar)
Hex value is obtained by	: ADC value x 02h/FFh
Temperature: (5-50°C)	: ADC value x 32h/FFh
Humidity: (0-99%)	: ADC value x 63h/FFh

These hex values are then converted to decimal for viewing on the LCD.

ASSUMPTIONS :

1. We have assumed there is an uninterrupted power supply.
2. That the analog signal is directly fed to the input of ADC.
3. The .asm file is compiled and the executable file is stored permanently in the ROM.
4. Initially the processor checks for the memory location FFFF0h with a jump instruction to the beginning of the code.
5. The temperature which is being measured will not affect the processor.
The display on the LCD displays an average of the previous 30 values read, i.e., the previous hour.

6. When each time the user presses the external button, the clocks are not reset, implying that the next reading continues to take place as per the original 2 minute scheme which is set. On the button press, a new value is taken, added to data stored in memory and then, the past 30 values are taken for averaging, scaling and displaying on the LCD monitor.

7. The button press does not clash with the 2 minute interrupt in normal usage. This is a fair assumption to make as, the probability for the same is very small in real-time usage of the weather monitoring station.

8. In case of clash during operation (highly unlikely), and non-servicing of button interrupt, a second press will ensure the servicing of the interrupts, without affecting the 2 minute interrupt-servicing.

9. For the simulations and debugging, we have connected a faster (than 2 min) output of clock to see the output changes. In actual usage, 2 minute interrupt is used.

COMPONENTS USED IN THE DESIGN :

The 8086 based system uses the following chips or devices.

Chip number	Chip	Use
8086(1)	Microprocessor	Central Processing Unit
6116 (2)	SRAM – 2k	Random Access Memory to house DS and SS
2716 (4)	ROM – 2k	Read Only Memory to house the code
8255 (2)	Programmable Peripheral interface	Connections to various input and output device
KP125 (1) (0-2 bar)	Pressure Sensor	To measure the pressure
AD8494 (1) (5-50 C)	Temperature Sensor	To measure the temperature
HYT271 (1) (0-99%)	Humidity Sensor	To measure the humidity
ADC – 0808(1)	Analog to Digital Converter	Converts analog data to its digital equivalent
74LS244(1)	8-bit unidirectional Bus Buffer	Buffering Control Buses
74LS245(2)	8-bit bidirectional Bus Buffer	Buffering Data Buses
74LS373(3)	Octal latch	To latch Address Bus
8284A(1)	Clock generator	Generates frequency of 5MHz
Switch(1)	Push button switch	To provide user interface
LM 016L (3)	LCD(liquid crystal display)	To display data
74LS138 (2)	Decoder	To provide addressing logic
8253A (2)	Software-controlled hardware timer	To generate pulse for ADC and provide delays of 2 min and 1 hr.
8259	Priority Interrupt Controller	To handle interrupts from four sources.

WMT52	*Wind Speed Sensor*	*To measure wind speed*

***AND and OR gates have been used as per requirements.**

MEMORY INTERFACING :

The memory interfaced uses 6116 RAM chips and 2716 ROM chips to interface a total of 8k of ROM and 4k of RAM. Addressing starts at 00000h so that the complete memory addressing is as:

ROM1 – 00000h-00FFFh

RAM1 – 02000h-02FFFh

ROM2 – FF000h - FFFFFh

Both, even and odd banks have been incorporated in the design. The decoding logic is obtained from:

ROM1-00000H-00FFFH

A_{19}	A_{18}	A_{17}	A_{16}	A_{15}	A_{14}	A_{13}	A_{12}	A_{11}	A_{10}	A_9	A_8	A_7	A_6	A_5	A_4	A_3	A_2	A_1	A_0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1

ROM2 (Fold back)-FF000H-FFFFFH

A_{19}	A_{18}	A_{17}	A_{16}	A_{15}	A_{14}	A_{13}	A_{12}	A_{11}	A_{10}	A_9	A_8	A_7	A_6	A_5	A_4	A_3	A_2	A_1	A_0
1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

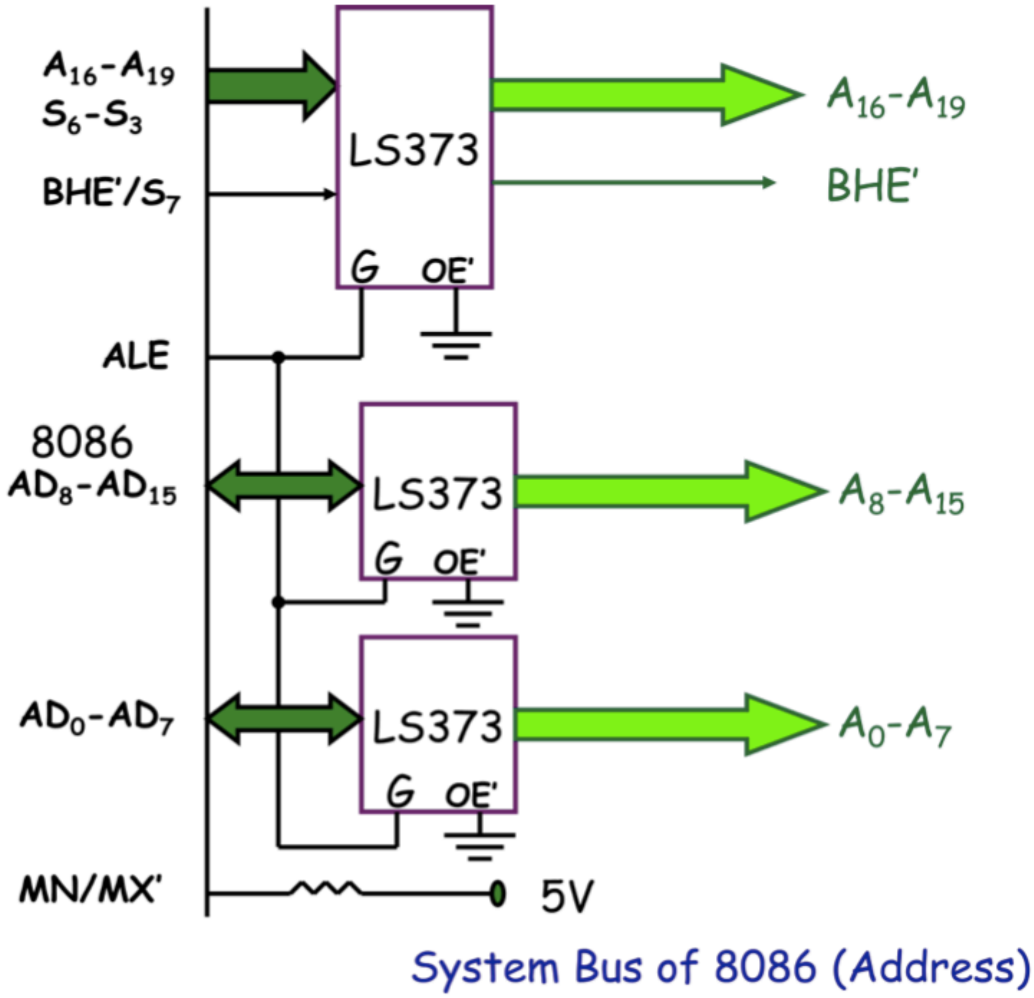
RAM1-01000H -01FFFH

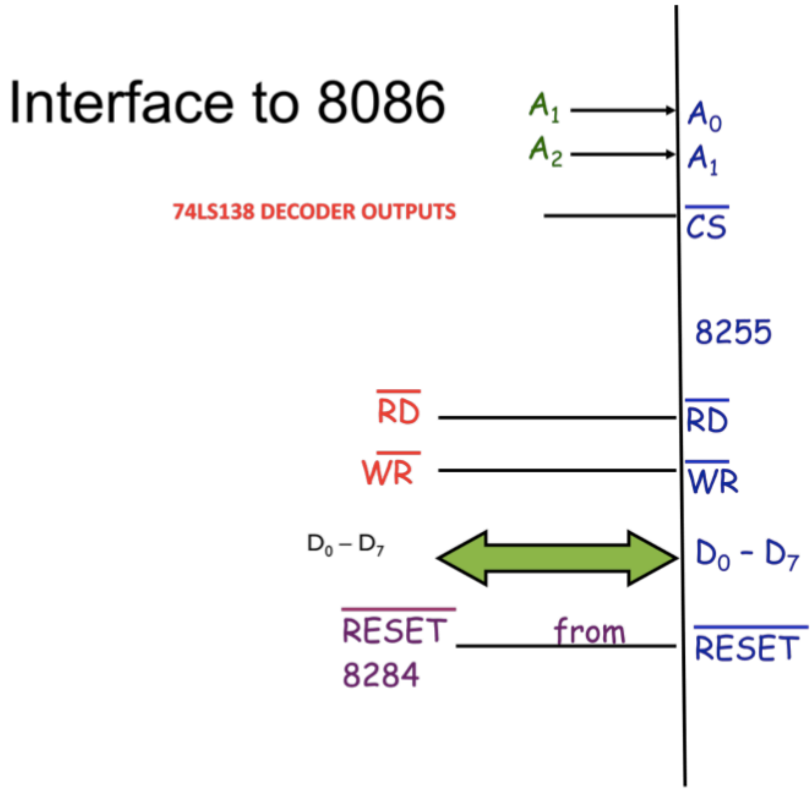
A_{19}	A_{18}	A_{17}	A_{16}	A_{15}	A_{14}	A_{13}	A_{12}	A_{11}	A_{10}	A_9	A_8	A_7	A_6	A_5	A_4	A_3	A_2	A_1	A_0
0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1

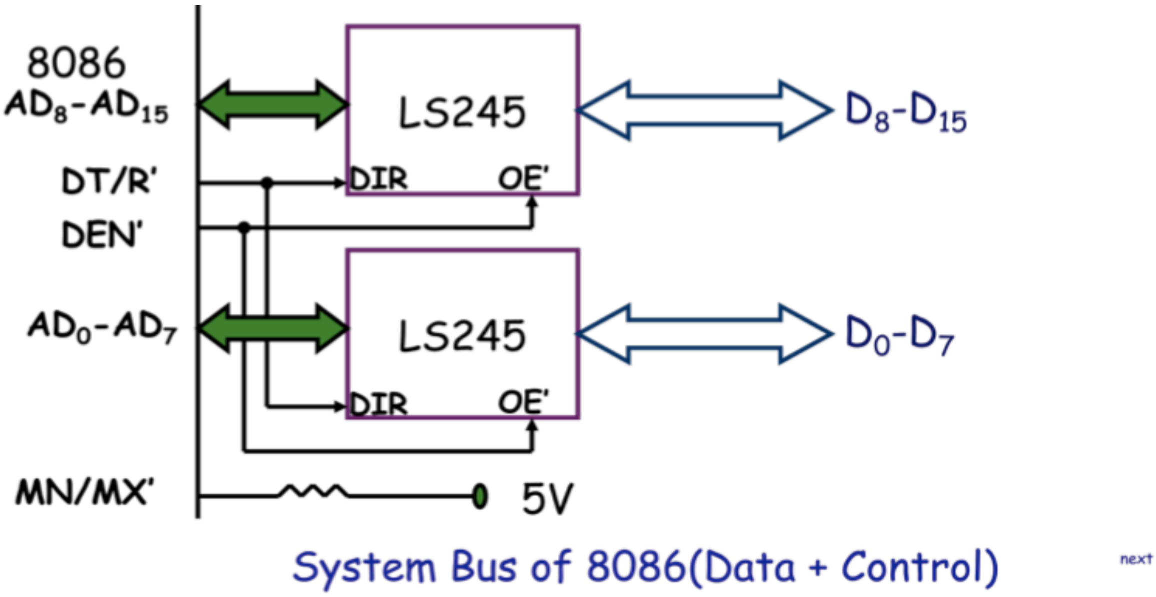
THE IVT TABLE :

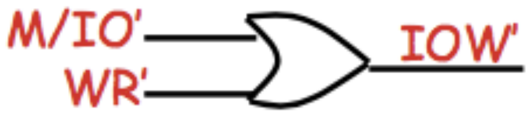
Vector Number	ISR
80h	0202h : 0200h
81h	0206h : 0204h
82h	020Ah : 0208h
83h	020Eh : 020Ch

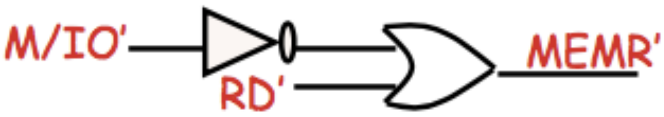
CIRCUIT COMPONENTS :




Interface to 8086
A1
A2
A0
A1
74LS138 DECODER OUTPUTS
CS
8255
RD
RD
WR
WR
D0 – D7
D0 - D7
RESET
from
8284
RESET

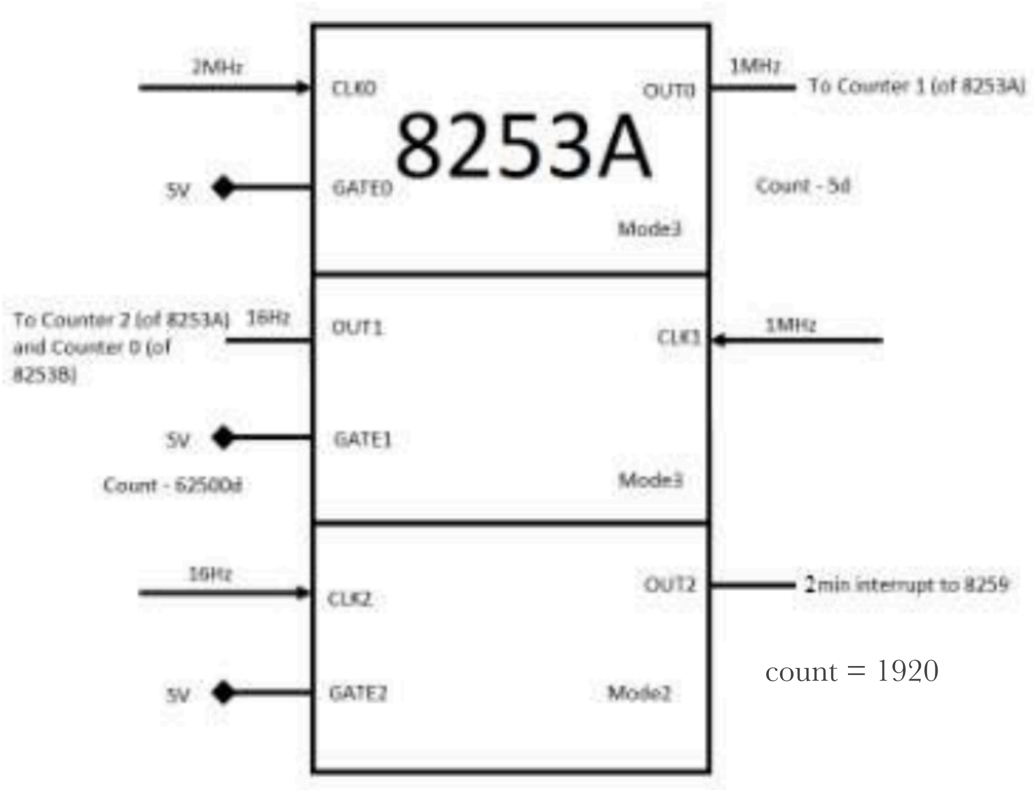

8086
AD8-AD15
LS245
D8-D15
DT/R'
DIR
OE'
DEN'
AD0-AD7
LS245
D0-D7
DIR
OE'
MN/MX'
5V
System Bus of 8086(Data + Control)
next

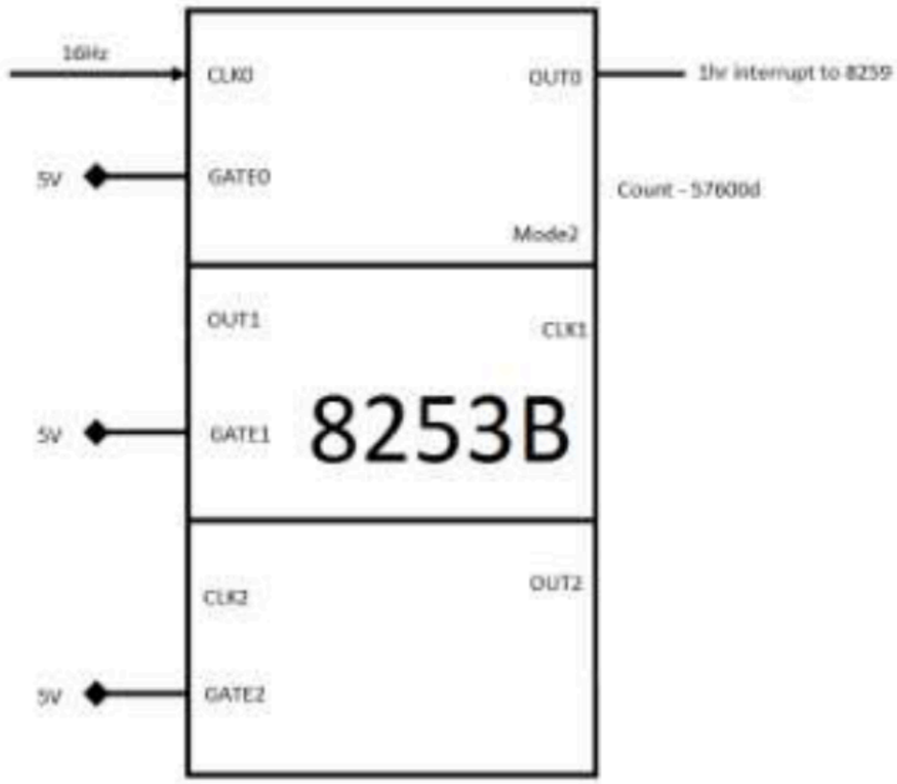


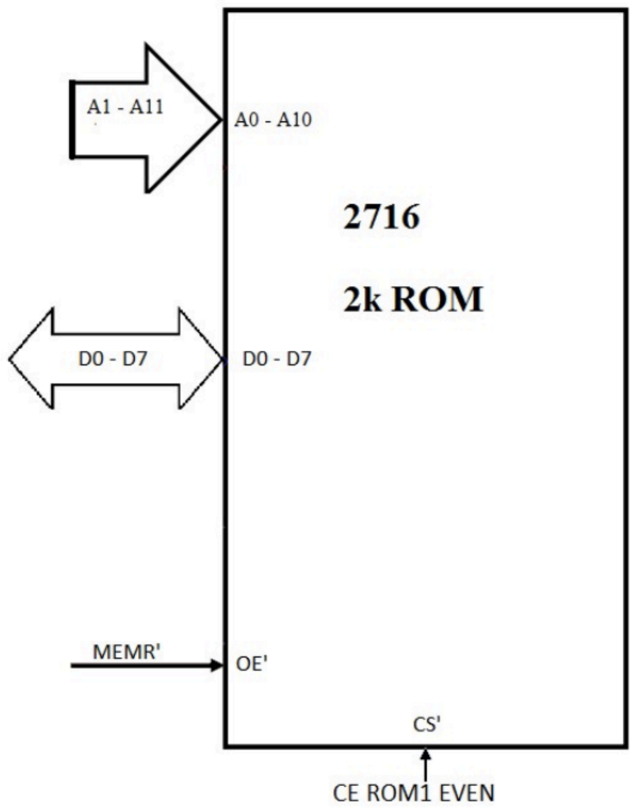


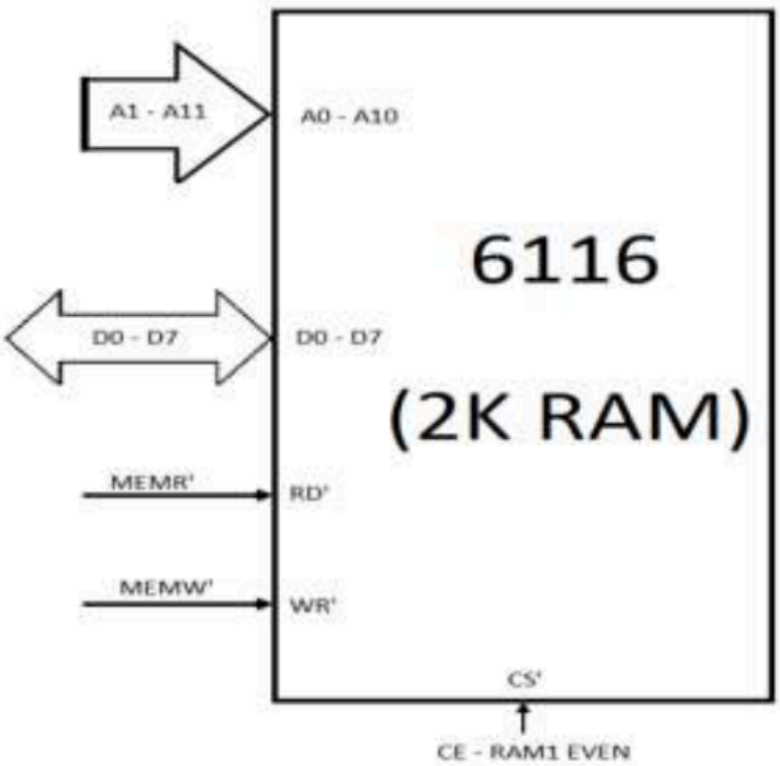
- System bus control and data

- **8253- Timer**

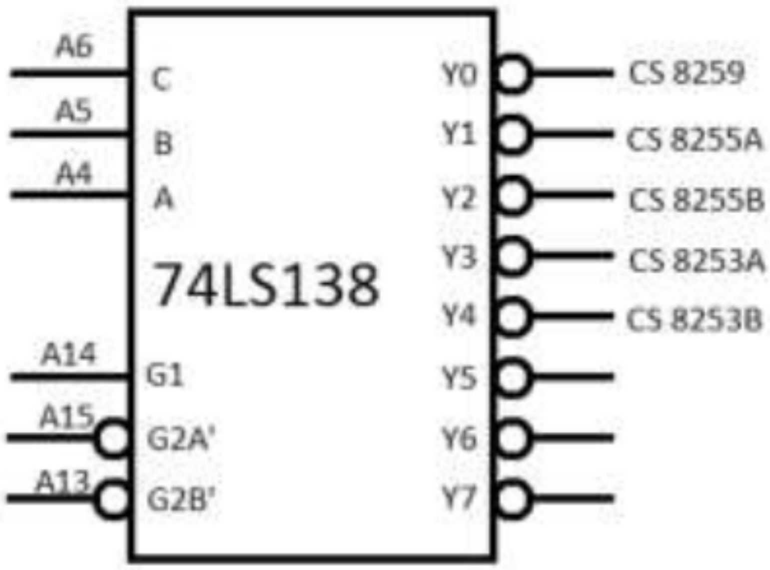

8253A
2MHz
CLK0
OUT0
1MHz
To Counter 1 (of 8253A)
5V
GATE0
Count - 5d
Mode3
To Counter 2 (of 8253A) and Counter 0 (of 8253B)
16Hz
OUT1
CLK1
1MHz
5V
GATE1
Count - 62500d
Mode3
16Hz
CLK2
OUT2
2min interrupt to 8259
count = 1920
5V
GATE2
Mode2

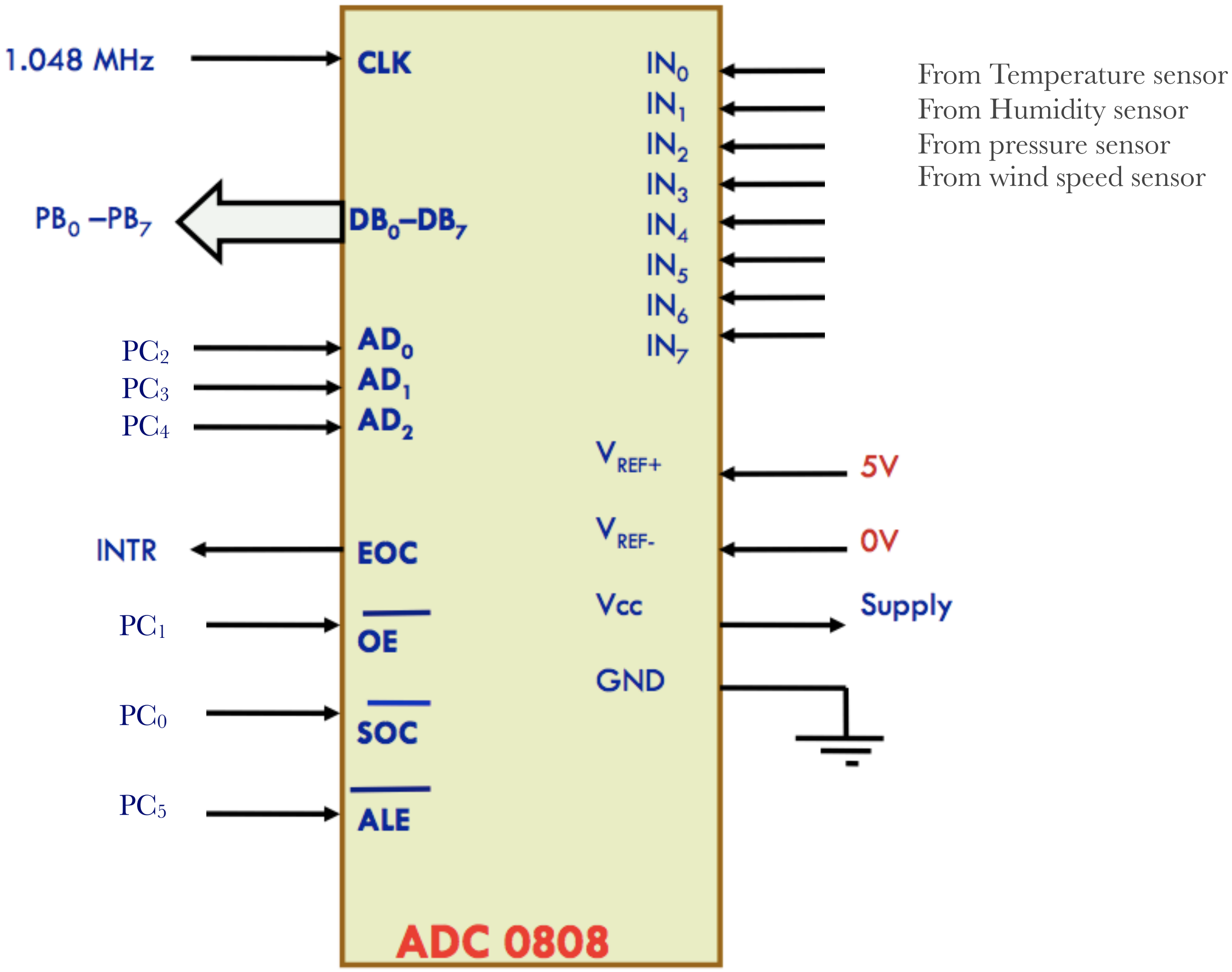

16Hz
CLK0
OUT0
1hr interrupt to 8259
5V
GATE0
Count - 57600d
Mode2
OUT1
CLK1
5V
GATE1
8253B
CLK2
OUT2
5V
GATE2


A1 - A11
A0 - A10
2716
2k ROM
D0 - D7
D0 - D7
MEMR'
OE'
CS'
CE ROM1 EVEN

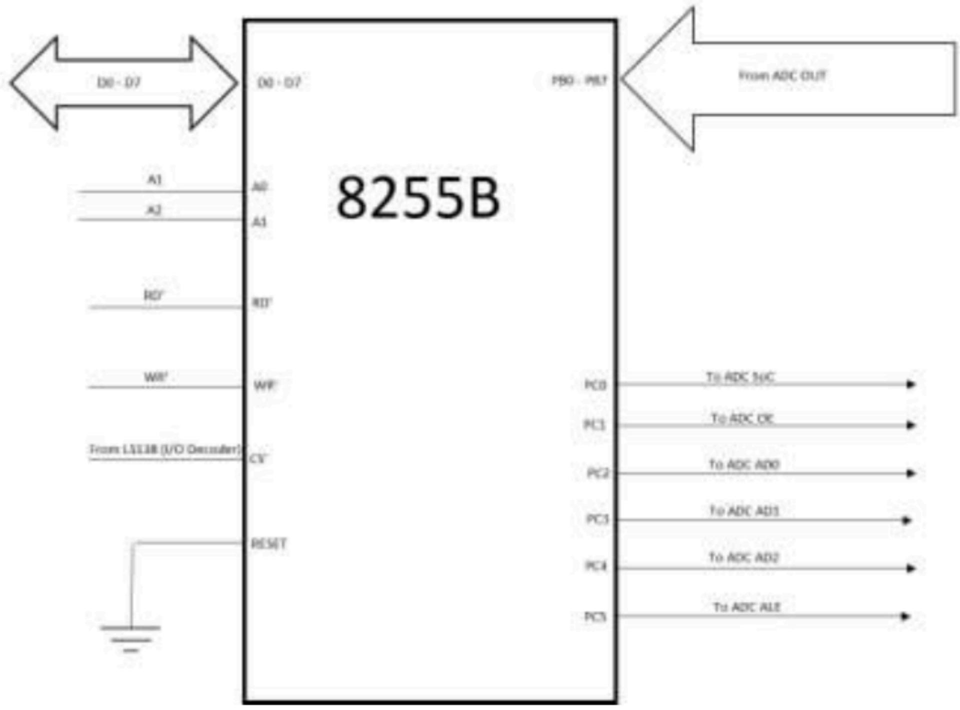

A1 - A11
A0 - A10
6116
D0 - D7
D0 - D7
(2K RAM)
MEMR'
RD'
MEMW'
WR'
CS'
CE - RAM1 EVEN

- IO-decoder

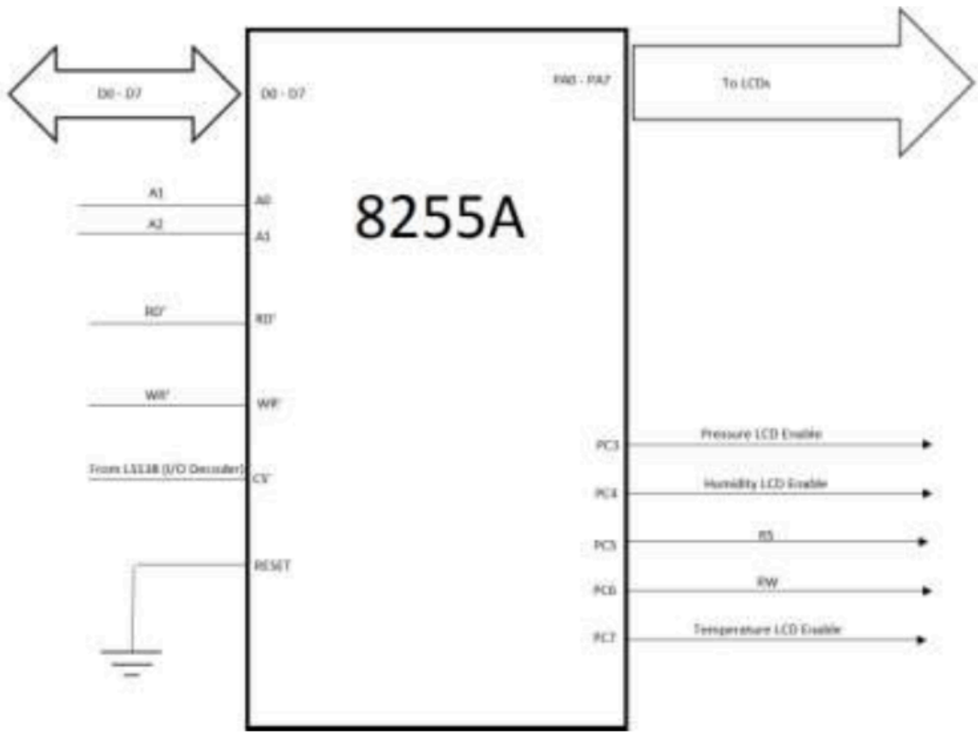

A6
A5
A4
C
B
A
74LS138
A14
A15
A13
G1
G2A'
G2B'
Y0
Y1
Y2
Y3
Y4
Y5
Y6
Y7
CS 8259
CS 8255A
CS 8255B
CS 8253A
CS 8253B


1.048 MHz
CLK
PB0 –PB7
DB0–DB7
PC2
PC3
PC4
AD0
AD1
AD2
INTR
EOC
PC1
OE
PC0
SOC
PC5
ALE
IN0
IN1
IN2
IN3
IN4
IN5
IN6
IN7
From Temperature sensor
From Humidity sensor
From pressure sensor
From wind speed sensor
VREF+
5V
VREF-
0V
Vcc
Supply
GND
ADC 0808

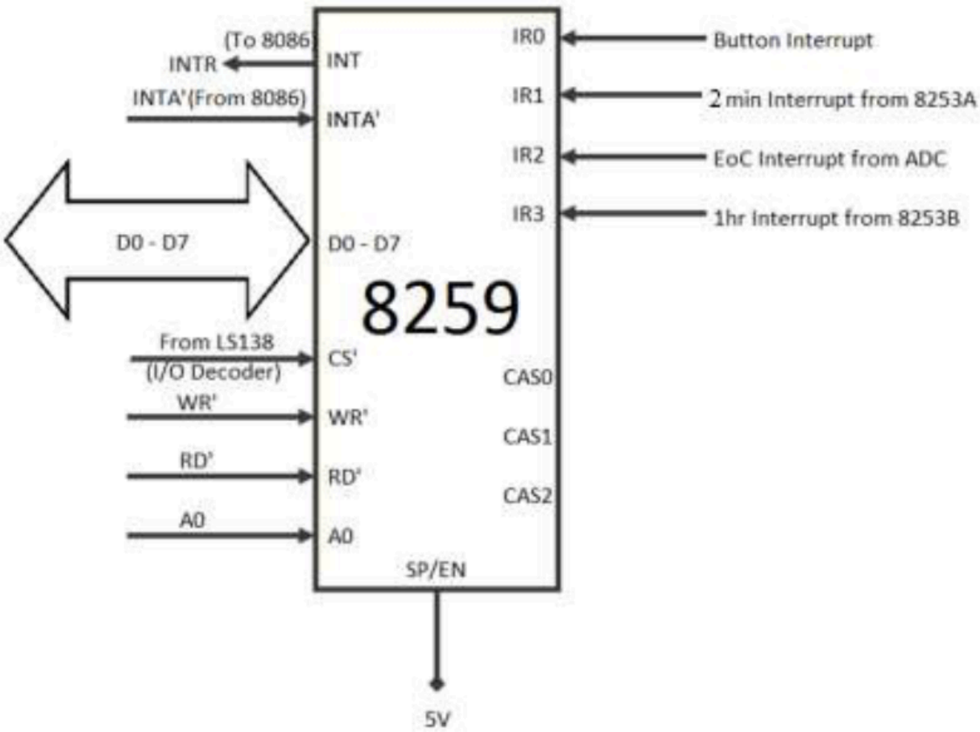
- 8255-B: (For the ADC)



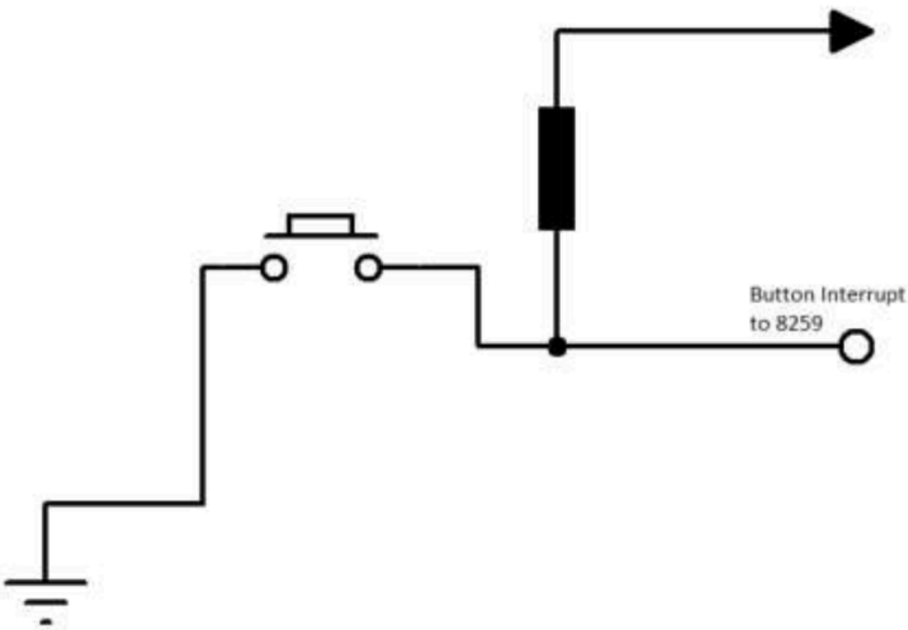
- 8255-A: (For display)



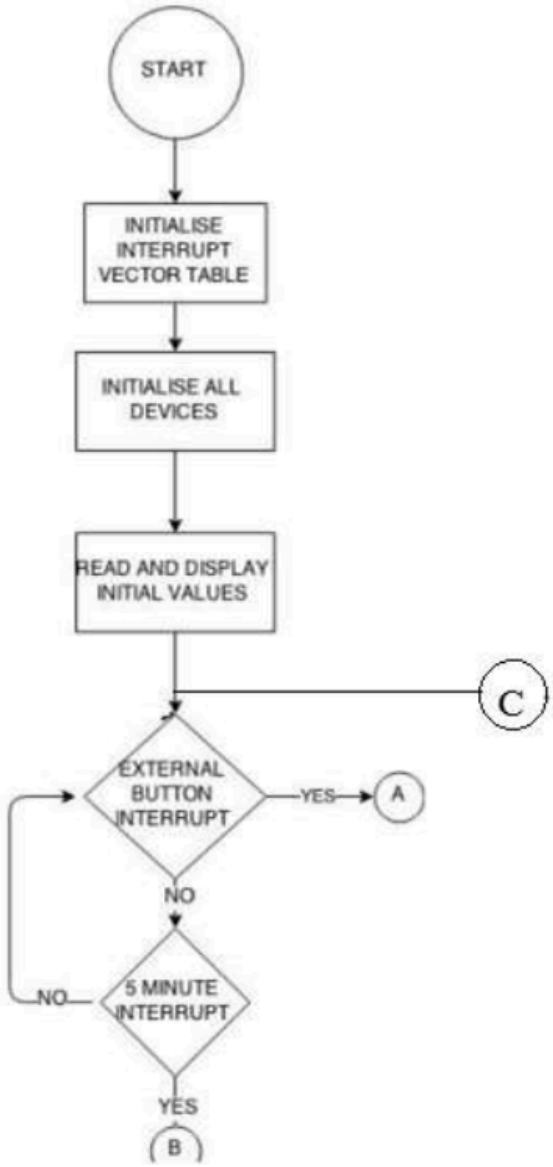
- 8259:

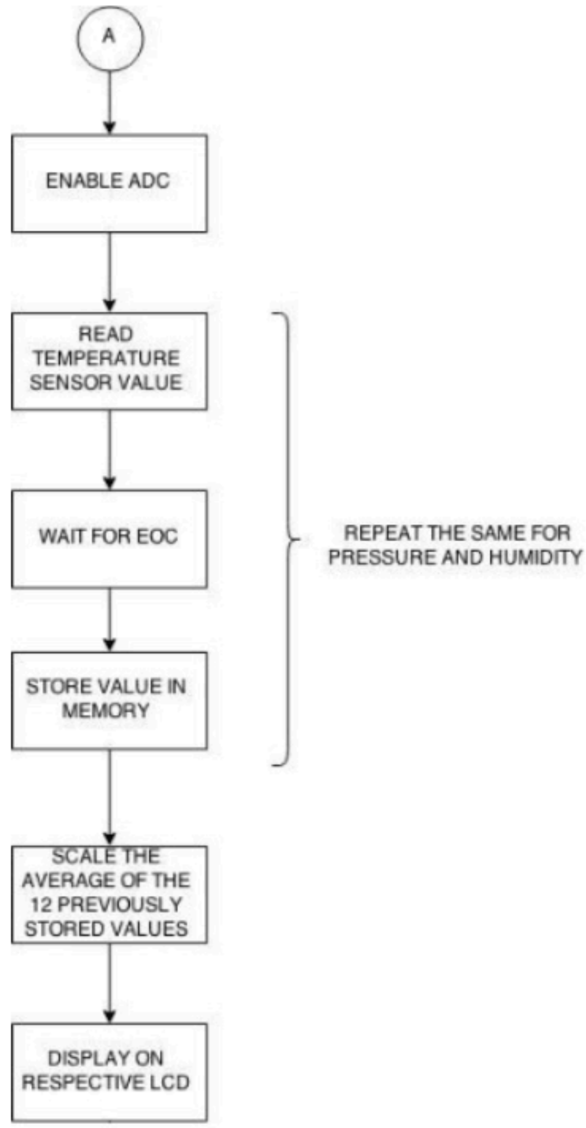


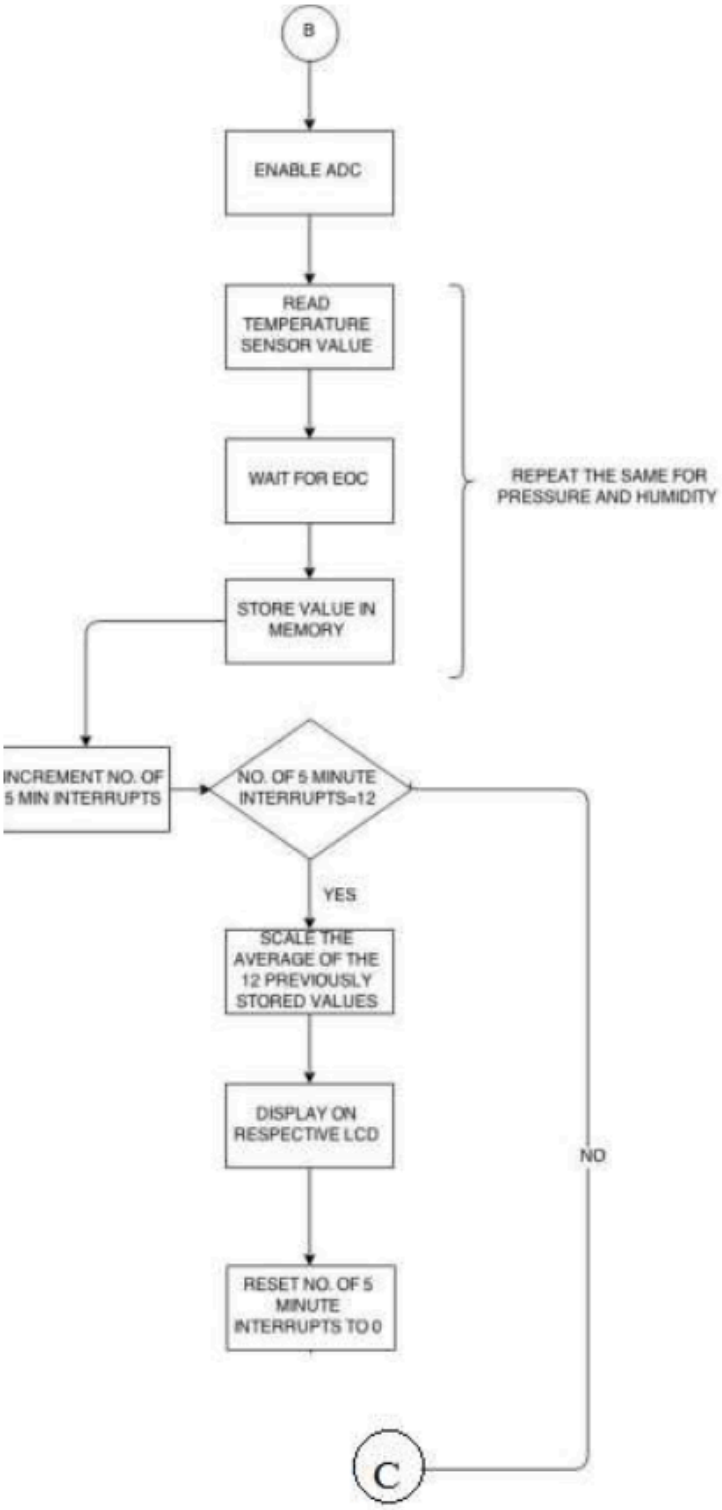
- Button



ALGORITHM_FLOWCHART :


START
INITIALISE INTERRUPT VECTOR TABLE
INITIALISE ALL DEVICES
READ AND DISPLAY INITIAL VALUES
C
EXTERNAL BUTTON INTERRUPT
YES
A
NO
5 MINUTE INTERRUPT
NO
YES
B


A
ENABLE ADC
READ TEMPERATURE SENSOR VALUE
WAIT FOR EOC
STORE VALUE IN MEMORY
REPEAT THE SAME FOR PRESSURE AND HUMIDITY
SCALE THE AVERAGE OF THE 12 PREVIOUSLY STORED VALUES
DISPLAY ON RESPECTIVE LCD


B
ENABLE ADC
READ TEMPERATURE SENSOR VALUE
WAIT FOR EOC
STORE VALUE IN MEMORY
REPEAT THE SAME FOR PRESSURE AND HUMIDITY
INCREMENT NO. OF 5 MIN INTERRUPTS
NO. OF 5 MINUTE INTERRUPTS=12
YES
SCALE THE AVERAGE OF THE 12 PREVIOUSLY STORED VALUES
DISPLAY ON RESPECTIVE LCD
RESET NO. OF 5 MINUTE INTERRUPTS TO 0
NO
C

- **CODE**

```
#MAKE_COM#

#LOAD_SEGMENT=0100h#

#LOAD_OFFSET=0000h#

#CS=0100h#

#IP=0000h#

#DS=0000h#

#ES=0000h#

#SS=0000h#

#SP=FFFEh#

#AX=0000h#

#BX=0000h#

#CX=0000h#

#DX=0000h#

#SI=0000h#

#DI=0000h#

#BP=0000h#


;------------------------IVT-init----------------------;


mov ax, offset isr0

mov [00200h], ax

mov ax, seg isr0

mov [00202h], ax

mov ax, offset isr1

mov [00204h], ax

mov ax, seg isr1

mov [00206h], ax

mov ax, offset isr2
```

```
mov [00208h], ax

mov ax, seg isr2

mov [0020Ah], ax

mov ax, offset isr3

mov [0020Ch], ax

mov ax, seg isr3

mov [0020Eh], ax


;-------------------------IVT-init----------------------;

jmp start

db 512 dup(0)


;-------------------------Data-segment----------------------;


cstatea db 00h

cstateb db 00h

lcdln1 db 'Temp(C): '

lcdln2 db 16 dup('-')

lcdln3 db 16 dup('.')

lcdln4 db 16 dup('*')

lcdcnt1 db 9d

lcdcnt2 db 16d

lcdcnt3 db 16d

lcdcnt4 db 16d

flagcount dw 0

vals db 30 dup(0)

ctr dw 0

readyForHour db 1 dup(0)
```

```
thp db 1 dup(0)

lcdln11 db 'Humi1(%): '

lcdln22 db 16 dup('-')

lcdln33 db 16 dup('.')

lcdln44 db 16 dup('*')

lcdcnt11 db 9d

lcdcnt22 db 16d

lcdcnt33 db 16d

lcdcnt44 db 16d

;Humi~


flagcount11 dw 0

vals11 db 30 dup(0)

ctr11 dw 0

lcdln111 db 'Pres(Ba):'

lcdln222 db 16 dup('-')

lcdln333 db 16 dup('.')

lcdln444 db 16 dup('*')

lcdcnt111 db 9d

lcdcnt222 db 16d

lcdcnt333 db 16d

lcdcnt444 db 16d

;Pres


flagcount111 dw 0

vals111 db 30 dup(0)

ctr111 dw 0

numstr db 16 dup(0)
```

```
q db 0

r db 0

divby dw 30d

updatenow db 00h


;-----------------------start-inits----------------------;


start: cli

a8259 equ 4000h

a8255 equ 4010h

b8255 equ 4020h

a8253 equ 4030h

b8253 equ 4040h

8259_init:

;icw1


mov al, 00010011b ;ICW4 Needed (single 8259)

mov dx, a8259+00h ; dx has 1st address of 8259

out dx, al

;icw2


mov al, 10000000b ; dx has 2nd address of 8259

mov dx, a8259+02h ; 80h is generatedfor IR0 ie But-INT

out dx,al

;icw4


mov al, 00000011b ; rest follow 80h - 87h

out dx,al
```

```
;ocw1

mov al, 11111110b ; non buffered mode with AEOI enabled
out dx, al
; Initialising 8255A ...

8255_init:
mov al, 10000010b ;Cmnd Word - port a(o/p), !(prt B: i/p)
mov dx, a8255+06h
out dx, al
; !(Same as prev 8255) B - i/p C - for controlling ADC

mov al, 10000010b
mov dx, b8255+06h
out dx, al
8253_init: ; counter0 - sq. wave - binary i/p(2MHz-i/p)
;1Mhz

mov al, 00010110b
mov dx, a8253+06h
out dx, al
mov al, 02h
mov dx, a8253+00h ; To divide by 2 - to give 1MHz
out dx, al
;16hz

mov al, 01110110b ;counter1 - sq. wave - binary i/p
mov dx, a8253+06h
```

```
out dx, al
mov al, 24h ; count = 62500 = 0f424h
mov dx, a8253+02h
out dx, al
mov al, 0F4h
out dx, al
;2-min

mov al, 10110100b ;cntr3 - Using mode 2 - every 2 min(low)
mov dx, a8253+06h ;Must be inverted and given as interrupt
out dx, al
mov al, 80h ; if 2min, load 0C0
mov dx, a8253+04h
out dx, al
mov al, 07h ; if 2min, load 12h
out dx, al
;1hr

mov al, 00110100b ;counter 0 - 16Hz to 1Hr pulse (obsolete)
mov dx, b8253+06h
out dx, al
mov al, 00h
mov dx, b8253+00h
out dx, al
mov al, 0E1h
out dx, al
LCD_init:
lcden equ 80h
```

```
lcdrw equ 40h

lcdrs equ 20h

aclrb lcdrw

lcd_out 38h

lcd_out 0Eh

lcd_out 06h

lcd_clear

LCD_init1:

lcden1 equ 10h

lcdrw equ 40h

lcdrs equ 20h

aclrb lcdrw

lcd_out1 38h

lcd_out1 0Eh

lcd_out1 06h

lcd_clear

LCD_init11:

lcden11 equ 08h

lcdrw equ 40h

lcdrs equ 20h

aclrb lcdrw

lcd_out11 38h

lcd_out11 0Eh

lcd_out11 06h

lcd_clear


;-----------------------start-code------------------------;

; Perform Initial display ...
```

```
;turn on adc - temperature

mov thp,00h
int 81h
;wait for eoc

eocint08:
mov dx, a8255+02h
in al, dx
mov bl, al
and bl, 08h
jnz eocint08
eocint18:
mov dx, a8255+02h
in al, dx
mov bl, al
and bl, 08h
jz eocint18
;Store Values - Temperature

mov thp,00h
int 83h
;Repeat process for Humi~ty
mov thp,01h
int 81h ; do same for humi~
;wait for eoc

eocint010:
```

```
mov dx, a8255+02h
in al, dx
mov bl, al
and bl, 08h
jnz eocint010
eocint101:
mov dx, a8255+02h
in al, dx
mov bl, al
and bl, 08h
jz eocint101
mov thp,01h
int 83h
; FOR pressure

mov thp,11h
int 81h ; do same for humi
;wait for eoc

eocint0109:
mov dx, a8255+02h
in al, dx
mov bl, al
and bl, 08h
jnz eocint0109
eocint1018:
mov dx, a8255+02h
in al, dx
```

```
mov bl, al

and bl, 08h

jz eocint1018

mov thp,11h

int 83h

mov thp,00h

int 82h

mov thp,01h

int 82h

mov thp,11h

int 82h

; --------END of initial display ---------------

;poll portb of a8255 forever

xinf:

;check if button is pressed using a flag stored in memory


mov al, updatenow

cmp al, 01h

jnz cont

mov updatenow, 00h

mov thp,00h ;FOR TEMPERATURE

int 81h ;turn on adc

;wait for eoc


eocint0:

mov dx, a8255+02h

in al, dx

mov bl, al
```

```
and bl, 08h
jnz eocint0
eocint1:
mov dx, a8255+02h
in al, dx
mov bl, al
and bl, 08h
jz eocint1
mov thp,00h
int 83h
mov thp,01h
int 81h ; do same for humi
;wait for eoc

eocint00:
mov dx, a8255+02h
in al, dx
mov bl, al
and bl, 08h
jnz eocint00
eocint11:
mov dx, a8255+02h
in al, dx
mov bl, al
and bl, 08h
jz eocint11
mov thp,01h
int 83h
```

```
mov thp,11h ; FOR PRESSURE

int 81h

;wait for eoc


eocint000:

mov dx, a8255+02h

in al, dx

mov bl, al

and bl, 08h

jnz eocint000

eocint111:

mov dx, a8255+02h

in al, dx

mov bl, al

and bl, 08h

jz eocint111

mov thp,11h

int 83h

mov thp,00h

int 82h

mov thp,01h

int 82h

mov thp,11h

int 82h

;regular polling


cont:

mov dx, a8255+02h
```

```
in al, dx
mov bl, al
and bl, 01h
jz butint
mov bl, al
and bl, 02h
jz twomin
mov bl, al
and bl, 04h
jz onehr
mov bl, al
and bl, 08h
jz eocint
jmp xinf
;low logic detected. Wait for whole pulse

butint:
in al, dx
and al, 01h
jz butint
int 80h
jmp xinf
twomin:
in al, dx
and al, 02h
jz twomin
mov thp,00h
int 81h
```

```
eocint09:
mov dx, a8255+02h
in al, dx
mov bl, al
and bl, 08h
jnz eocint09
eocint19:
mov dx, a8255+02h
in al, dx
mov bl, al
and bl, 08h
jz eocint19
mov thp,00h
int 83h
mov thp,01h
int 81h
;wait for eoc

eocint009:
mov dx, a8255+02h
in al, dx
mov bl, al
and bl, 08h
jnz eocint009
eocint119:
mov dx, a8255+02h
in al, dx
mov bl, al
```

```
and bl, 08h
jz eocint119
mov thp,01h
int 83h
mov thp,11h
int 81h
;wait for eoc

eocint00999:
mov dx, a8255+02h
in al, dx
mov bl, al
and bl, 08h
jnz eocint00999
eocint11999:
mov dx, a8255+02h
in al, dx
mov bl, al
and bl, 08h
jz eocint11999
mov thp,11h
int 83h
;Change value of no. of 2 min intervals taken during simulation

inc readyForHour
cmp readyForHour,02h
jnz donotcallonehour
mov thp,00h
```

```
int 82h ; Call the 1 hour interrupt
mov thp,01h
int 82h
mov thp,11h
int 82h
mov readyForHour,00h ; Reset the 30, 2-min interval count
donotcallonehour: jmp xinf
; Obsolete. Is not use as intrpt is called directly
onehr:
in al, dx
and al, 04h
jz onehr
int 82h
jmp xinf
eocint:
in al, dx
and al, 08h
jz eocint
mov thp,00h
int 83h
mov thp,01h
int 83h
mov thp,11h
int 83h
jmp xinf
jmp quit
;-----------------------start-macros----------------------;
pushall macro
```

```
push ax
push bx
push cx
push dx
push si
push di
endm
popall macro
pop di
pop si
pop dx
pop cx
pop bx
pop ax
endm
;set/clear pins since BSR was being strange


asetb macro mbit
pushall
mov al, mbit
mov bl, cstatea
or al, bl
mov dx, a8255+04h
out dx, al
mov bl, al
mov cstatea, bl
popall
endm
```

```
aclrb macro mbit
pushall
mov al, mbit
xor al, 0FFh
mov bl, cstatea
and al, bl
mov dx, a8255+04h
out dx, al
mov bl, al
mov cstatea, bl
popall
endm
adcst equ 01h
adcoe equ 02h
adcA equ 04h
adcB equ 08h
adcC equ 10h
adcALE equ 20h
bsetb macro mbit
pushall
mov al, mbit
mov bl, cstateb
or al, bl
mov dx, b8255+04h
out dx, al
mov bl, al
mov cstateb, bl
popall
```

```
endm
bclrb macro mbit
pushall
mov al, mbit
xor al, 0FFh
mov bl, cstateb
and al, bl
mov dx, b8255+04h
out dx, al
mov bl, al
mov cstateb, bl
popall
endm
lcd_out macro dat
aclrb lcdrs
pushall
mov al, dat
mov dx, a8255+00h
out dx, al
asetb lcden
aclrb lcden
call delay_20ms
popall
endm
lcd_out1 macro dat
aclrb lcdrs
pushall
mov al, dat
```

```
mov dx, a8255+00h
out dx, al
asetb lcden1
aclrb lcden1
call delay_20ms
popall
endm
lcd_out11 macro dat
aclrb lcdrs
pushall
mov al, dat
mov dx, a8255+00h
out dx, al
asetb lcden11
aclrb lcden11
call delay_20ms
popall
endm
lcd_write_char macro dat
asetb lcdrs
pushall
mov al, dat
mov dx, a8255+00h
out dx, al
asetb lcden
aclrb lcden
call delay_20ms
popall
```

```
endm
lcd_write_char1 macro dat
asetb lcdrs
pushall
mov al, dat
mov dx, a8255+00h
out dx, al
asetb lcden1
aclrb lcden1
call delay_20ms
popall
endm
lcd_write_char11 macro dat
asetb lcdrs
pushall
mov al, dat
mov dx, a8255+00h
out dx, al
asetb lcden11
aclrb lcden11
call delay_20ms
popall
endm
lcd_clear macro
lcd_out 01h
endm
;division routine since div was acting strange
wow_divide macro div
```

```
pushall
mov cx, 00
mov bx, divi
loopy:
sub ax, bx
inc cx
cmp ax, 0
jge loopy
dec cx
add ax, bx
mov r, al
mov q, cl
popall
endm
wow_divide1 macro divi
pushall
mov cx, 00
mov bx, divi
loopy1:
sub ax, bx
inc cx
cmp ax, 0
jge loopy1
dec cx
add ax, bx
mov r, al
mov q, cl
popall
```

```
endm
wow_divide2 macro divi
pushall
mov cx, 00
mov bx, divi
loopy2:
sub ax, bx
inc cx
cmp ax, 0
jge loopy2
dec cx
add ax, bx
mov r, al
mov q, cl
popall
endm
;------------------------Start-Procedure Defs-----------------------;
;delay proc: just a huge loop
delay_20ms proc near
mov dx, 10
r1: mov cx, 2353
r2: loop r2
dec dx
jne r1
ret
delay_20ms endp
;write a string in memory to LCD
write_string proc near
```

```
lea si, lcdln1
mov cl, lcdcnt1
l1: lcd_write_char [si]
inc si
loop l1
ret
write_string endp
;write a string in memory to LCD
write_string1 proc near
lea si, lcdln11
mov cl, lcdcnt11
l11: lcd_write_char1 [si]
inc si
loop l11
ret
write_string1 endp
;write a string in memory to LCD
write_string11 proc near
lea si, lcdln111
mov cl, lcdcnt111
l111: lcd_write_char11 [si]
inc si
loop l111
ret
write_string11 endp
;-----------------------------------------------
;Scale Humidity
convert_humi proc near
```

```
;get it to scale (0-99%)
mov ah, 00h
mov al, q
mov bl, 99d
mul bl
mov bl, 0FFh ;FFh is the max o/p from ADC
div bl
;split the numbers
mov ah, 00h
mov bl, 10d
div bl
lea si, numstr ;Load appropriate ascii value(quo)
add ax, 3030h
mov [si], al
mov [si+1], ah
mov al, r
mov ah, 00h
mov bx, 100d
mul bx
mov bl, 30d
div bl
mov ah, 00h
mov bl, 10d
div bl
add ax, 3030h
mov [si+2], al ;Load appropriate ascii value(rem)
mov [si+3], ah
ret
```

```
convert_humi endp
; Scaling fns ----------------------------------------------
;Scale temperature
convert_temp proc near
;get it to scale (5-50 C)
mov ah, 00h
mov al, q
mov bl, 45d
mul bl
mov bl, 0FFh
div bl
add ax, 05h
;split the numbers
mov ah, 00h
mov bl, 10d
div bl
lea si, numstr
add ax, 3030h
mov [si], al
mov [si+1], ah
mov al, r
mov ah, 00h
mov bx, 100d
mul bx
mov bl, 30d
div bl
mov ah, 00h
mov bl, 10d
```

```
div bl
add ax, 3030h
mov [si+2], al
mov [si+3], ah
ret
convert_temp endp
;-------------------------------------------------------------------------
;Scale Pressure
convert_pres proc near
;get it to scale (0-2 Bar)
mov ah, 00h
mov al, q
mov bl, 02d
mul bl
mov bl, 0FFh ;FFh is the max o/p from ADC
div bl
;split the numbers
mov ah, 00h
mov bl, 10d
div bl
lea si, numstr ;Load appropriate ascii value(quo)
add ax, 3030h
mov [si], al
mov [si+1], ah
mov al, r
mov ah, 00h
mov bx, 100d
mul bx
```

```
mov bl, 30d
div bl
mov ah, 00h
mov bl, 10d
div bl
add ax, 3030h
mov [si+2], al ;Load appropriate ascii value(rem)
mov [si+3], ah
ret
convert_pres endp
;output ascii equiv values on LCD from mem location
num_out proc near
lcd_out 01h
lea si, lcdln1
mov cl, lcdcnt1
lx1: lcd_write_char [si]
inc si
loop lx1
;call write_string
mov al, numstr
mov ah, numstr+1
lcd_write_char al
lcd_write_char ah
lcd_write_char '.'
mov al, numstr+2
mov ah, numstr+3
lcd_write_char al
lcd_write_char ah
```

```
ret
num_out endp
;output ascii equiv values on LCD from mem location
num_out1 proc near
lcd_out1 01h
lea si, lcdln11
mov cl, lcdcnt11
lx11: mov bl, [si]
lcd_write_char1 bl
add si, 1
loop lx11
;call write_string1
mov al, numstr
mov ah, numstr+1
lcd_write_char1 al
lcd_write_char1 ah
lcd_write_char1 '.'
mov al, numstr+2
mov ah, numstr+3
lcd_write_char1 al
lcd_write_char1 ah
ret
num_out1 endp
num_out11 proc near
lcd_out11 01h
;call write_string11
lea si, lcdln111
mov cl, lcdcnt111
```

```
lx111: lcd_write_char11 [si]
inc si
loop lx111
mov al, numstr
mov ah, numstr+1
lcd_write_char11 al
lcd_write_char11 ah
lcd_write_char11 '.'
mov al, numstr+2
mov ah, numstr+3
lcd_write_char11 al
lcd_write_char11 ah
ret
num_out11 endp
; ------------------------ End of procedure Defs -------------------------
;-----------------------Start Of ISRs----------------------;
;2 minute interrupt
isr1:
; First make OE high PC1
bsetb adcoe
cmp thp,00h
jnz humiisr1
;Assuming that CBA is connected to PC 4-3-2
;select channel 000
bclrb adcA
bclrb adcB
bclrb adcC
;Now make a high-low pulse on ALE;PC5
```

```
bsetb adcALE

bclrb adcALE

;High-low pulse on SOC - connected to PC0

bsetb adcst

bclrb adcst

;now wait for EOC interrupt

jmp isr1end

humiisr1: ; thp == 1

cmp thp,01h

jnz presisr1

;select channel 001

bsetb adcA

bclrb adcB

bclrb adcC

;Now make a high-low pulse on ALE;PC5

bsetb adcALE

bclrb adcALE

;High-low pulse on SOC - connected to PC0

bsetb adcst

bclrb adcst

jmp isr1end

presisr1:

;select channel 010

bclrb adcA

bsetb adcB

bclrb adcC

;Now make a high-low pulse on ALE;PC5

bsetb adcALE
```

```
bclrb adcALE
;High-low pulse on SOC - connected to PC0
bsetb adcst
bclrb adcst
isr1end:
iret
;EOC interrupt
isr3:
cmp thp,00h
jnz humiisr3
mov dx, b8255+02h
in al, dx
;Finally make OE low
bclrb adcoe
cmp flagcount, 0
jnz x4
;for the first hour, flagcnt = 0; for consecutive iterations, it'll be >0
mov bx, ctr
lea si, vals
mov [si+bx], al
inc bx
mov ctr, bx
cmp bx, 30
jnz x5
mov flagcount, 1
mov ctr, 0
jmp endisr1
x4: mov bx, ctr
```

```
lea si, vals
mov [si+bx], al
inc bx
cmp bx, 30
jnz x5
mov bx, 0
x5: mov ctr, bx
jmp endisr1
humiisr3: ;thp == 1
cmp thp,01h
jnz presisr3
mov dx, b8255+02h
in al, dx
;Finally make OE low
bclrb adcoe
cmp flagcount11, 0
jnz x41
mov bx, ctr11
lea si, vals11
mov [si+bx], al
inc bx
mov ctr11, bx
cmp bx, 30
jnz x51
mov flagcount11, 1
mov ctr11, 0
jmp endisr1
x41: mov bx, ctr11
```

```
lea si, vals11
mov [si+bx], al
inc bx
cmp bx, 30
jnz x51
mov bx, 0
x51: mov ctr11, bx
jmp endisr1
presisr3:
mov dx, b8255+02h
in al, dx
;Finally make OE low
bclrb adcoe
cmp flagcount111, 0
jnz x411
mov bx, ctr111
lea si, vals111
mov [si+bx], al
inc bx
mov ctr111, bx
cmp bx, 30
jnz x511
mov flagcount111, 1
mov ctr111, 0
jmp endisr1
x411: mov bx, ctr111
lea si, vals111
mov [si+bx], al
```

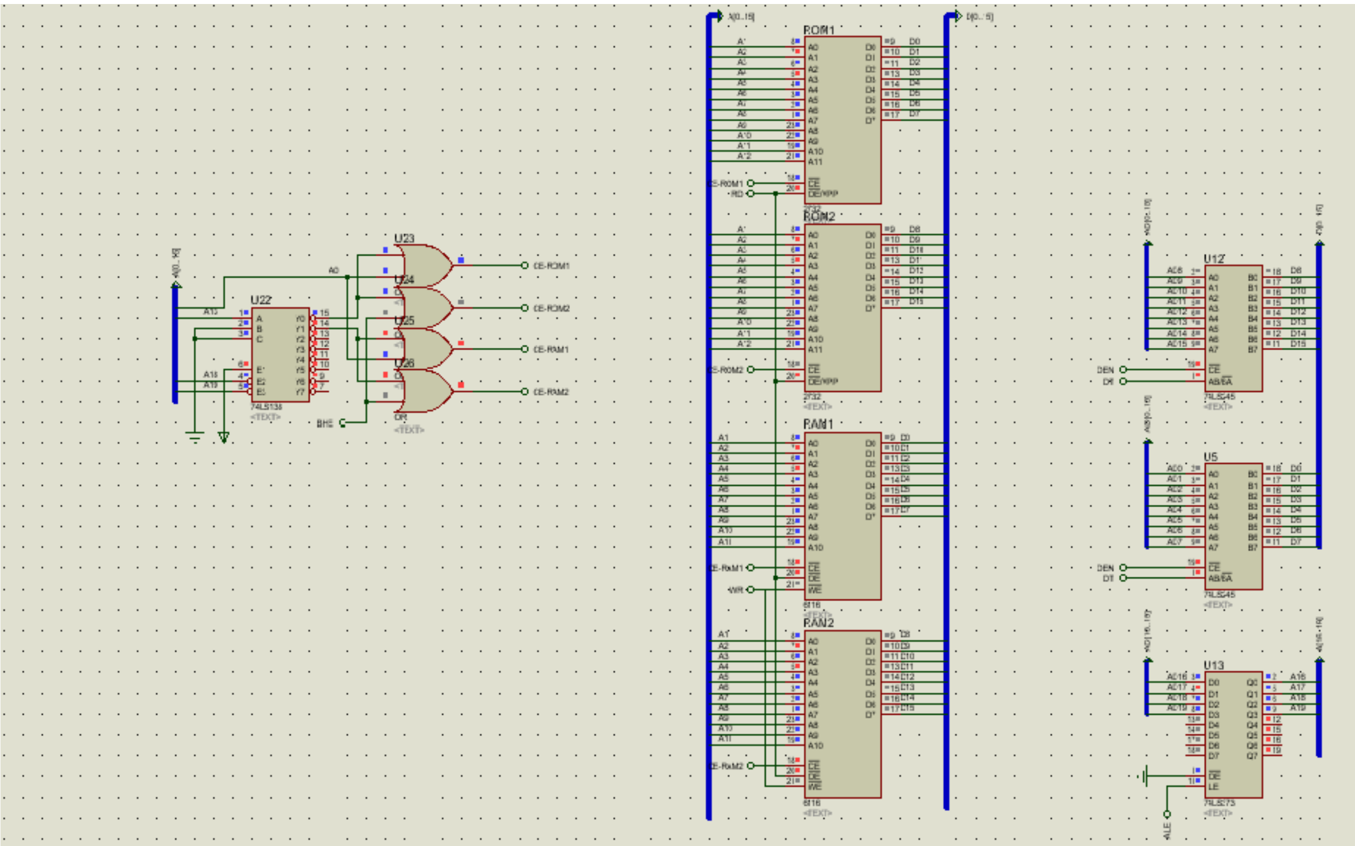
```
inc bx
cmp bx, 30
jnz x511
mov bx, 0
x511: mov ctr111, bx
endisr1:
iret
;1hr int
isr2:
cmp thp,00h
jnz humiisr2
mov bx, 00h
mov cx, 30d
lea si, vals
xadd:
mov dl, [si]
mov dh, 00h
add bx, dx
inc si
dec cx
jnz xadd
mov ax, bx
mov dx, flagcount
cmp dx, 1
jnz x2
mov divby, 30d
jmp x3
x2:
```

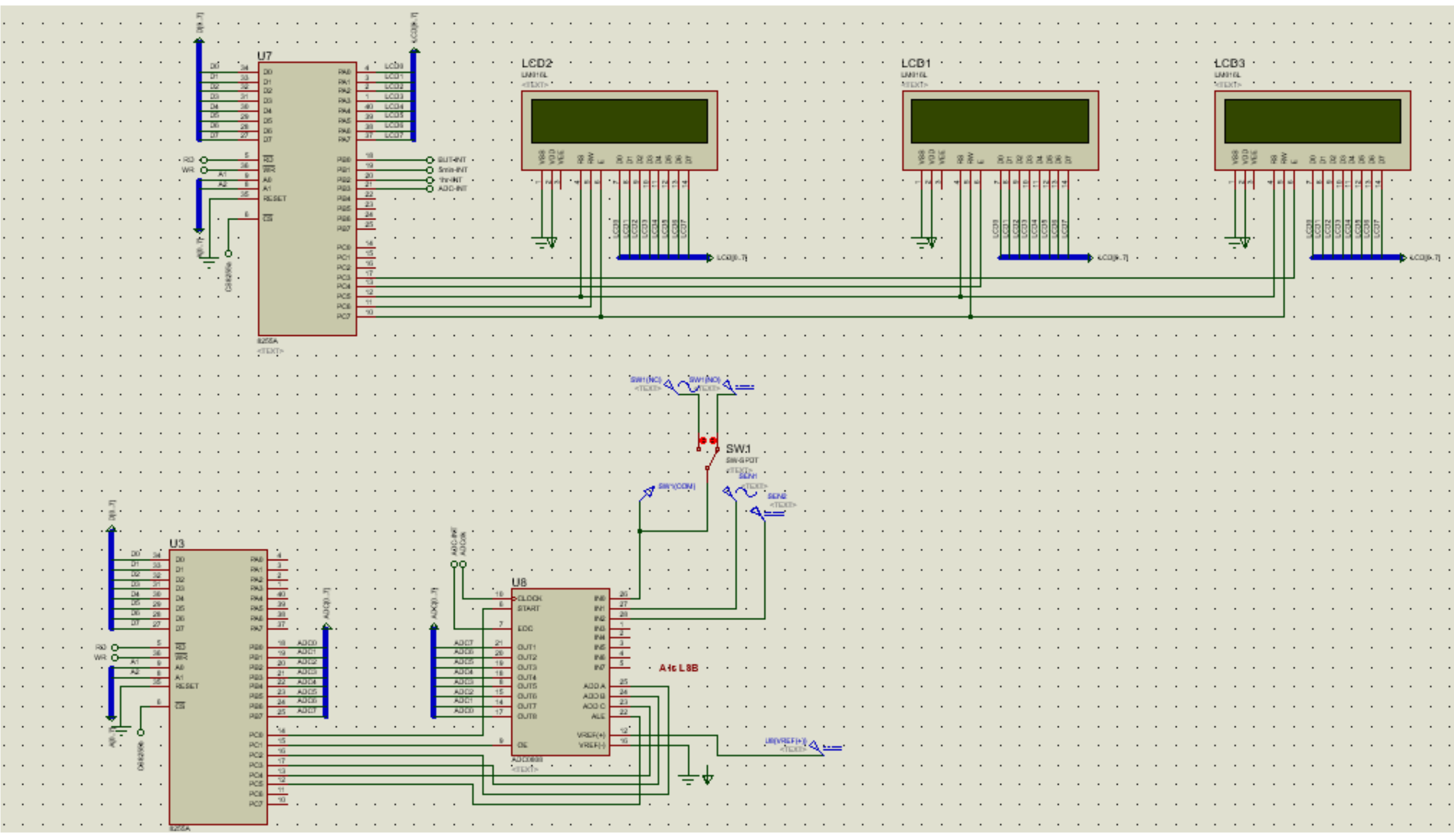
```
mov dx, ctr
mov divby, dx
x3:
wow_divide divby
call convert_temp
call num_out
jmp endisr2:
humiisr2:
cmp thp,01h
jnz presisr2
mov bx, 00h
mov cx, 30d
lea si, vals11
xadd1:
mov dl, [si]
mov dh, 00h
add bx, dx
inc si
dec cx
jnz xadd1
mov ax, bx
mov dx, flagcount11
cmp dx, 1
jnz x21
mov divby, 30d
jmp x31
x21:
mov dx, ctr11
```

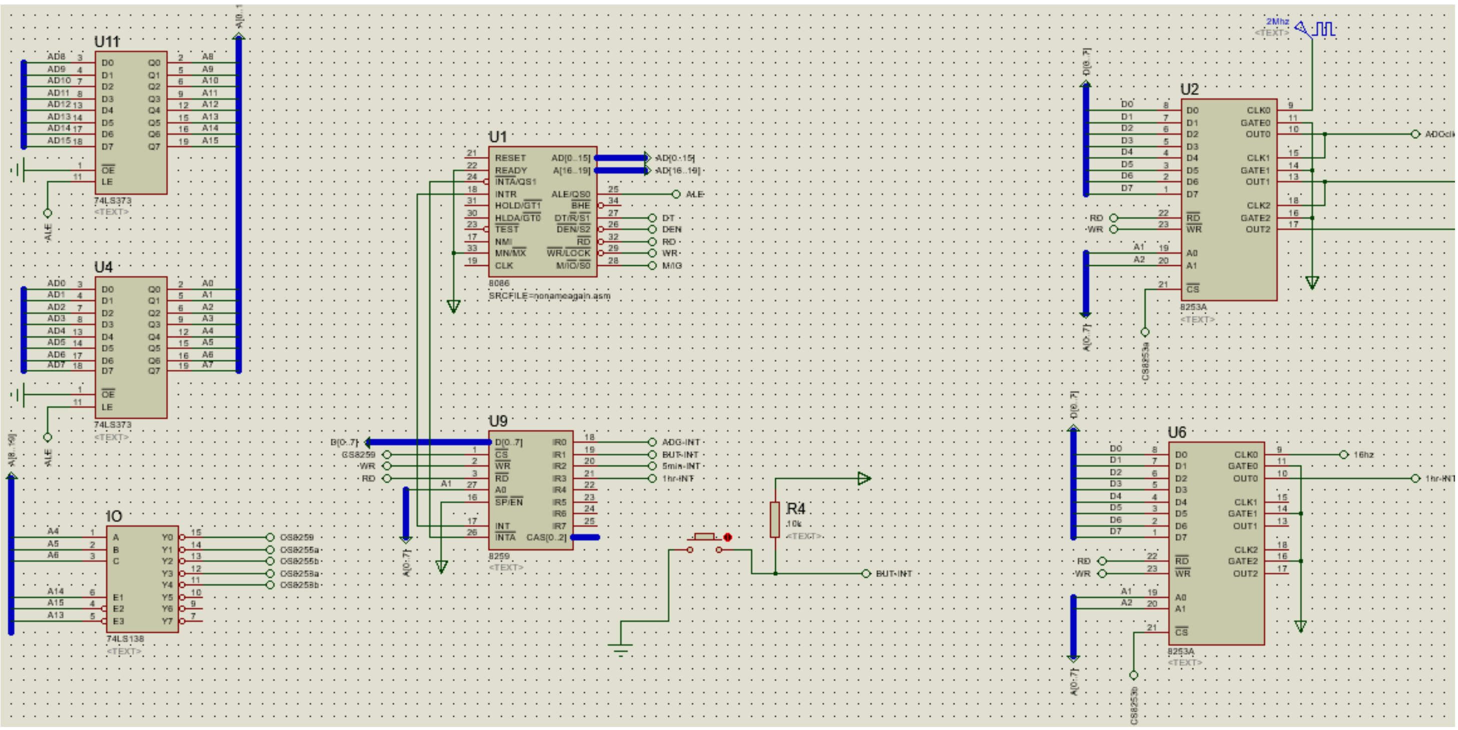
```
mov divby, dx
x31:
wow_divide1 divby
call convert_humi
call num_out1
jmp endisr2
presisr2:
mov bx, 00h
mov cx, 30d
lea si, vals111
xadd11:
mov dl, [si]
mov dh, 00h
add bx, dx
inc si
dec cx
jnz xadd11
mov ax, bx
mov dx, flagcount111
cmp dx, 1
jnz x211
mov divby, 30d
jmp x311
x211:
mov dx, ctr111
mov divby, dx
x311:
wow_divide2 divby
```

```
call convert_pres
call num_out11
endisr2:
iret
;button interrupt
isr0:
mov updatenow, 01h
iret
;-----------------------END OF ISRs------------------------;
quit:
hlt
```

PROTEUS SIMULATION SCREEN SHOTS :







WMT52 Ultrasonic Wind Sensor

The Vaisala WINDCAP® Ultrasonic Wind Sensor WMT52.

Features/Benefits

- Measures horizontal wind speed and wind direction
- Triangular design ensures excellent data availability
- No moving parts
- Maintenance-free
- Optional heating available
- Compact, durable and robust
- Low power consumption
- IP66 housing with mounting kit
- Applications: marine, wind energy, environmental monitoring

Proven Vaisala Performance

The Vaisala WINDCAP® Ultrasonic Wind Sensor WMT52 incorporates decades of Vaisala experience in wind measurement using ultrasound to determine horizontal wind speed and direction.

With no moving parts, the WMT52 has high sensitivity as the measurement time constant and starting threshold are virtually zero. This makes it superior to the conventional mechanical wind sensors.

The WMT52 is designed to operate without periodic field calibration and maintenance.

Applications

The WMT52 is ideal for use in marine applications as the housing with the mounting kit is water resistant. The WMT52 is also suitable for wind energy and environmental monitoring, for example, for measuring the distribution of air pollution and road tunnel ventilation.

Easy to Install

The WMT52 is delivered fully assembled and configured from the factory. With the Vaisala Configuration Software Tool you can change the settings, such as averaging times, output mode, update intervals, measured variables and message contents.

The WMT52 can be mounted either on top of a pole mast or on a cross arm.

When using the optional mounting kit, the north alignment needs to be performed only once.

Heating

The optional heating available in the WMT52 assists measurements in the freezing weather conditions and during snowfall.

As the heating circuit is independent of the operational power, separate supplies can be used. Heating is switched on automatically at low temperatures, well before the freezing point.

Low Power Consumption

The WMT52 has very low power consumption; during the idle mode the device typically consumes about 2 ... 3 mW.

VAISALA www.vaisala.com

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Technical Data

Wind

WIND SPEED	
Range	0 ... 60 m/s
Response time	250 ms
Available variables	average, maximum, and minimum
Accuracy	±3% at 10m/s
Output resolution	0.1 m/s (km/h, mph, knots)
WIND DIRECTION	
Azimuth	0 ... 360°
Response time	250 ms
Available variables	average, maximum, and minimum
Accuracy	±3°
Output resolution	1°
MEASUREMENT FRAME	
Averaging time	1 ... 3600 s (=60 min), at one second steps on the basis of samples taken at 4 Hz rate (configurable)
Update interval	1 ... 3600 s (=60 min), at one-second steps

General

Self-diagnostics	separate supervision message, unit/status fields to validate measurement quality
Start-up	automatic, <10 s from power on to the first valid output
Serial data interface	SDI-12, RS-232, RS-485, RS-422, USB connection
Communication protocols	SDI-12 v1.3, ASCII automatic & polled, NMEA 0183 v. 3.0 with query option
Baud rate	1200 ... 115 200
Operating temperature	-52 ... +60 °C (-60 ... +140 °F)
Storage temperature	-60 ... +70 °C (-76 ... +158 °F)
Dimensions	
height	139 mm (5.7")
diameter	114 mm (4.49")
weight	510 g (1.12 lb)
Housing	IP65
Housing with mounting kit	IP66
Vibration	IEC 60945 paragraph 8

Power Supply

Operating voltage	5 ... 32 VDC
Power consumption on average	
minimum	0.1 mA at 12 VDC
maximum	14 mA at 5 VDC
typical	3 mA at 12 VDC (default measuring intervals)
Heating voltage	5 ... 32 VDC / 5 ... 30 VAC_{RMS})

Accessories

Mounting kit	212792
Bird spike kit	212793
Surge protector for sensor	WSP150

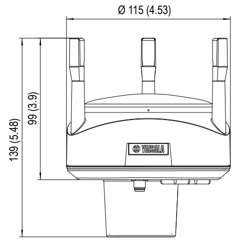
Electromagnetic Compatibility

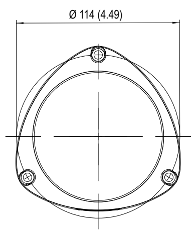
Complies with EMC standard: EN61326-1, Industrial Environment

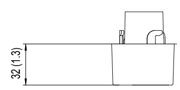
IEC standards	IEC 60945/61000-4-2 ... 61000-4-6

Dimensions

Dimensions in mm (inches)







mounting kit

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www.vaisala.com

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Preliminary Technical Data

Thermocouple Amplifiers With Cold Junction Compensation

AD8494/AD8495/AD8496/AD8497

FEATURES

Easy to use
Internal cold junction compensation
High impedance differential input
Reference pin allows offset adjustment
Thermocouple break detection
Wide power supply range
- **Single supply: 2.7 V to 36 V**
- **Dual supply: ±2.7 V to ±18 V**

RoHS compliant
180 µA supply current
8-pin MSOP

APPLICATIONS

J or K type thermocouple measurement
Oven measurements
Exhaust gas temperature sensing

FUNCTIONAL BLOCK DIAGRAM

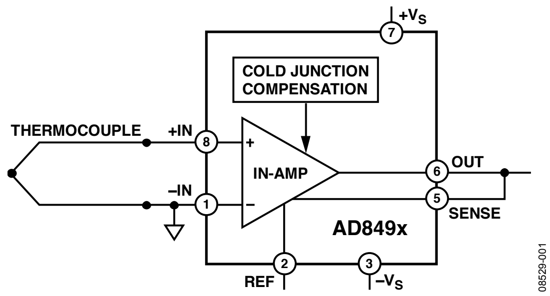

Figure 1.

GENERAL DESCRIPTION

The AD8494/AD8495/AD8496/AD8497 are easy to use amplifiers for J and K type thermocouples. These amplifiers convert the small voltage generated by a thermocouple junction into a signal that can easily be read by an analog-to-digital converter (ADC) or microcontroller. The gain from the thermocouple to the amplifier output is approximately 5 mV/°C.

The AD8494/AD8495/AD8496/AD8497 perform cold junction compensation using an on-board temperature sensor. Thermocouple measurements stay accurate through a wide range of ambient temperatures.

The AD8494/AD8495/AD8496/AD8497 contain a high precision instrumentation amplifier. This amplifier has high common-mode rejection, to block common-mode noise that the long lead thermocouples may pick up. For additional protection, the high impedance inputs of the amplifier make it easy to add extra filtering.

The AD8494/AD8495/AD8496/AD8497 allow a wide variety of supply voltages. With a 5 V single supply, the devices can cover nearly 1000 degrees of a thermocouple's temperature range.

The AD8494/AD8495/AD8496/AD8497 work with 3 V supplies, allowing them to directly interface to lower supply ADCs. They can also work with supplies as large as ±18 V in industrial systems that require a wide common-mode input range.

Whatever the supply rails, the AD8494/AD8495/AD8496/AD8497 can easily measure negative temperatures. The 0°C output can be adjusted with a voltage on the reference pin. This gives flexibility in adjusting the output range of the AD8494/AD8495/AD8496/AD8497 to fit the ADC.

The robust inputs are designed to handle real-world connection scenarios. The AD8494/AD8495/AD8496/AD8497 are robust to input voltages far beyond the supply rails. For example, with a ±5 V supply, the parts are guaranteed to withstand ±35 V at the input with no damage. Minimum and maximum input bias currents are specified to facilitate open thermocouple detection.

The AD8494/AD8495/AD8496/AD8497 are available in an 8-pin MSOP package and are fully RoHS compliant.

Table 1. Device Temperature Ranges

Part No.	Thermocouple Type	Optimized Temperature Range: Reference Junction	Optimized Temperature Range: Measurement Junction
AD8494	J	0°C to 50°C	Full J type range
AD8495	K	0°C to 50°C	Full K type range
AD8496	J	25°C to 100°C	Full J type range
AD8497	K	25°C to 100°C	Full K type range

Rev. PrA

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SPECIFICATIONS

$+V_S = 5$ V, $-V_S = 0$ V, $V_{IN+} = V_{IN-} = 0$ V, $V_{REF} = 0$ V, $T_A = T_R = 0°C$ to 100°C, $R_L = 100$ kΩ, unless otherwise noted. Table does not include gain and offset errors of the thermocouple itself. T_A is the ambient temperature at the AD849x; T_R is the thermocouple reference junction temperature; T_M is the thermocouple measurement junction temperature.

Table 2.

Parameter	Test Conditions/Comments	A Grade Min	A Grade Typ	A Grade Max	B Grade Min	B Grade Typ	B Grade Max	Unit
TEMPERATURE ACCURACY								
Initial Accuracy	AD8494/AD8495: $T_A = T_R = T_M = 25°C$ AD8496/AD8497: $T_A = T_R = 60°C$, $T_M = 25°C$			3			1	°C
Ambient Temperature Rejection	AD8494/AD8495: $T_A = T_R = 0°C$ to 50°C AD8496/AD8C497: $T_A = T_R = 25°C$ to 100°C			0.05			0.025	°C/°C
Gain Error[1,2]	AD8494/5: T_M = -200°C to 1200°C AD8496/7: T_M = -260°C to 1400°C		0.1			0.01		%
Nominal Transfer Function[1]			5			5		mV/°C
INPUTS								
Input Voltage Range		$-V_S - 0.2$		$+V_S - 1.6$	$-V_S - 0.2$		$+V_S - 1.6$	V
Overvoltage Range		$+V_S - 40$		$-V_S + 40$	$+V_S - 40$		$-V_S + 40$	V
Input Bias Current[3]			30			30		nA
Input Offset Current			0.5			0.5		nA
Common-Mode Rejection				0.2			0.1	°C/V
Power Supply Rejection				0.5			0.25	°C/V
NOISE								
Voltage Noise	f = 0.1 Hz to 10 Hz, $T_A = 25°C$		0.5			0.5		µV p-p
Voltage Noise Density	f = 1 kHz, $T_A = 25°C$		29			29		nV/√Hz
Current Noise Density	f = 1 kHz, $T_A = 25°C$		100			100		fA/√Hz
REFERENCE INPUT								
R_{IN}			50			50		kΩ
I_{IN}			22			22		µA
Voltage Range		$-V_S$		$+V_S$	$-V_S$		$+V_S$	V
Gain to Output			1			1		V/V
OUTPUT								
Output Voltage Range	R_L =100 kΩ to opposite supply	$-V_S + 0.05$		$+V_S - 0.1$	$-V_S + 0.05$		$+V_S - 0.1$	V
Short-Circuit Current[4]								mA
DYNAMIC RESPONSE								
−3 dB Bandwidth								
AD8494/AD8496			31			31		kHz
AD8495/AD8497			25			25		kHz
Settling Time								µs
POWER SUPPLY								
Operating Voltage Range[5]								
Single Supply		2.7		36	2.7		36	V
Dual Supply		±2.7		±18	±2.7		±18	V
Quiescent Current			180			180		µA

Parameter	Test Conditions/Comments	A Grade		B Grade		Unit
TEMPERATURE RANGE (T_A)						
Specified Performance						°C
AD8494/AD8495		0	50	0	50	°C/°C
AD8496/AD8497		25	100	25	100	°C/°C
Operational		−40	+125	−40	+125	°C

[1] Error does not include thermocouple gain error or thermocouple nonlinearity.
[2] With a 100 kΩ load, measurement junction temperatures beyond approximately 880°C for the AD8494/AD8496 and 960°C for the AD8495/AD8497 require supply voltages larger than 5 V or a negative voltage applied to the reference pin. Temperatures below 10°C require either a positive offset voltage applied to the reference pin or a negative supply.
[3] Input stage uses pnp transistors, so bias current always flows out of the part.
[4] Large output currents can increase the internal temperature rise of the part and contribute to cold junction compensation (CJC) error.
[5] Unbalanced supplies can also be used. Care should be taken that the common-mode voltage of the thermocouple stays within the input voltage range of the part.

ABSOLUTE MAXIMUM RATINGS

Table 3.

Parameter	Rating
Supply Voltage	±18 V
Output Short-Circuit Current	Indefinite
Maximum Voltage at –IN or +IN	$+V_S - 40$ V
Minimum Voltage at –IN or +IN	$-V_S + 40$ V
REF Voltage	$\pm V_S$
Storage Temperature Range	−65°C to +150°C
Specified Temperature Range	
AD8494/AD8495	0°C to 50°C
AD8496/AD8497	25°C to 100°C
Maximum IC Junction Temperature	140°C

Stresses above those listed under Absolute Maximum Ratings may cause permanent damage to the device. This is a stress rating only; functional operation of the device at these or any other conditions above those indicated in the operational section of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

THERMAL RESISTANCE

θ_{JA} is specified for a device in free air.

Table 4.

Package	θ_{JA}	Unit
8-Lead MSOP, 4-Layer JEDEC Board	135	°C/W

ESD CAUTION

ESD (electrostatic discharge) sensitive device. Charged devices and circuit boards can discharge without detection. Although this product features patented or proprietary protection circuitry, damage may occur on devices subjected to high energy ESD. Therefore, proper ESD precautions should be taken to avoid performance degradation or loss of functionality.

PIN CONFIGURATION AND FUNCTION DESCRIPTIONS

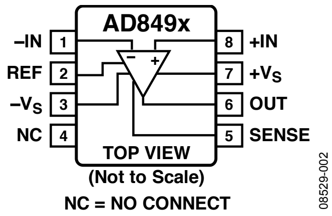

Figure 2. Pin Configuration

Table 5. Pin Function Descriptions

Pin No.	Mnemonic	Description
1	−IN	Negative Input.
2	REF	Reference. This pin must be driven by low impedance.
3	$-V_S$	Negative Supply.
4	NC	No Connect.
5	SENSE	Sense Pin. In measurement mode, connect to output; in setpoint mode, connect to setpoint voltage.
6	OUT	Output.
7	$+V_S$	Positive Supply.
8	+IN	Positive Input.

THEORY OF OPERATION

THERMOCOUPLE THEORY

A thermocouple consists of two dissimilar metals. These metals are connected at one end to form the measurement junction, sometimes also called the hot junction. This measurement junction is at the temperature to be measured. The other end of the thermocouple is connected to the metal lines that lead to the measurement electronics. This connection also forms a junction: the reference junction, also called the cold junction.

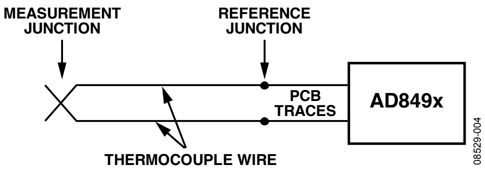

Figure 3. Thermocouple Junctions

Thermocouples create a differential voltage based on the temperature difference between the hot and cold junctions. The thermocouple voltage depends on both junction temperatures. Therefore, to derive the temperature at the measurement junction, the user must know two pieces of information: the differential voltage created by the thermocouple and the reference junction temperature. The use of the reference junction temperature, along with the thermocouple voltage reading, is typically called "cold junction compensation," because the electronics must compensate for any changes in temperature at the reference (cold) junction. Table 6 shows an example of a K type thermocouple voltage for various combinations of 0°C and 50°C on the reference and measurement junctions.

Table 6. K Type Thermocouple Voltages and AD8495 Readings

Measurement Junction Temperature	Reference Junction Temperature	Thermocouple Voltage	AD8495 Reading
50°C	0°C	2.023 mV	250 mV
50°C	50°C	0 mV	250 mV
0°C	0°C	0 mV	0 mV
0°C	50°C	−2.023 mV	0 mV

The voltage generated by a thermocouple is quite small. At room temperature, a K type thermocouple changes about 41 μV/°C, and a J type thermocouple changes about 52 μV/°C. Because the voltages generated are so small, thermocouple measurements are susceptible to interference.

The designer can take several steps to minimize possible interference.

- Measure thermocouples differentially to avoid ground loops.
- Filtering is typically recommended to remove high frequency noise and to protect against RFI interference.
- The signal conditioning circuitry should include a large amount of gain so that the small thermocouple signal can be read accurately by the components later in the signal chain.

Real-world thermocouples have variability in their metallurgical properties. These properties are reflected in specifications from the manufacturer for maximum error. Thermocouples are typically specified with an absolute temperature error, as well as with an error vs. temperature.

The voltage generated by a thermocouple is nonlinear. For example, whereas a J type thermocouple changes 52 μV/°C at +25°C, it changes by 47 μV/°C at −50°C, and by +55 μV/°C at 150°C. K type thermocouples tend to be more linear, staying fairly near 41 μV/°C when temperatures are above 0 μV/°C. Whether a thermocouple needs linearization depends on the thermocouple type chosen and the required system accuracy.

Thermocouple Tips

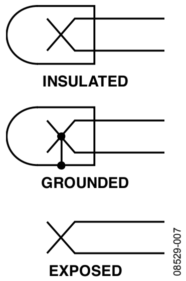

Figure 4. Thermocouple Measurement Junction Types

Thermocouple manufacturers offer three different styles for their measurement junctions:

- Insulated tip: The thermocouple manufacturer places a sheath around the thermocouple tip. The thermocouple tip is electrically isolated from the sheath, so that there is no electrical connection between the material being measured and the thermocouple. This thermocouple type is the most popular type on the market and is the easiest to use, but it has the slowest response time.
- Grounded: The thermocouple manufacturer places a sheath around the thermocouple tip, but the sheath is electrically connected to the thermocouple. Therefore, the thermocouple makes an electrical connection with the material being measured.
- Exposed: There is no protective sheath around the thermocouple tip, but there is an electrical connection between the thermocouple and the substance being measured. This type of thermocouple is the least robust but provides the fastest response time.

The type of thermocouple tip determines whether a ground connection should be made to the thermocouple in the signal conditioning system (see the Ground Connection section).

THERMOCOUPLE AMPLIFIER ARCHITECTURE

Figure 5 shows a block diagram of the AD849x circuitry. The AD849x consists of a low offset instrumentation amplifier and a temperature sensor. Figure 6 shows a simplified schematic with more detail.

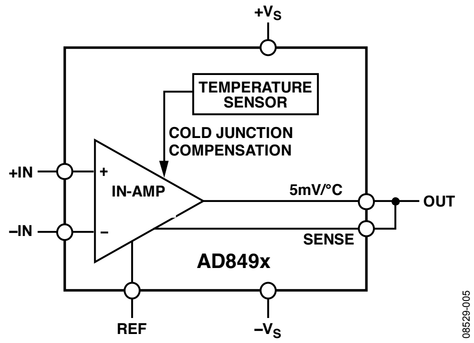

Figure 5. Block Diagram

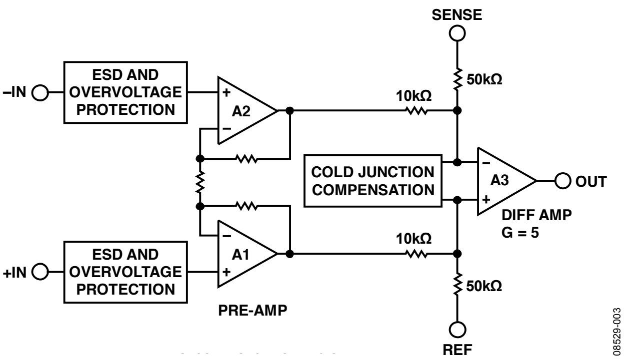

Figure 6. Simplified Schematics

Instrumentation Amplifier

As noted in the Thermocouple Theory section, the small thermocouple voltages require considerable gain before they can be sampled by typical ADCs. The gain for the instrumentation amplifier in each of the AD8494/AD8495/AD8496/AD8497 was chosen to provide a transfer function of approximately 5 mV/°C for the J and K thermocouple types.

The small signal strength means that thermocouple voltages are quite vulnerable to interference, especially when measured with single-ended amplifiers. The AD849x addresses this issue in several ways. The differential inputs of the device make grounding much more straightforward for thermocouples with insulated tips and is essential for thermocouples with grounded or exposed tips. The AD849x has excellent common-mode rejection, which prevents variations in ground potential from affecting the measurement. The AD849x also has low input bias currents, which allows for easy filtering at the inputs.

Cold Junction Compensation

The AD849x also includes a temperature sensor for cold junction compensation. This temperature sensor is used to measure the reference junction temperature of the thermocouple. This information is then fed into the instrumentation amplifier and is used to compensate the final output voltage. The cold junction compensation is optimized for 25°C in the AD8494/AD8495 for measurement systems typically at room temperature. It is optimized at 60°C in the AD8496/AD8497 for oven systems where the reference junction and signal conditioning circuitry typically sit at an elevated temperature.

Open Thermocouple Detection

The AD849x offers open thermocouple detection. The input bias current of the AD849x drives any unconnected input high and, therefore, rails the output. Whether the amplifier rails high or low depends on where the ground is connected: grounding the negative input causes the AD849x to rail high, whereas grounding the positive input causes the part to rail low. Note that this feature assumes no electrical connection at the thermocouple tip (see the Ground Connection section).

Transfer Function

The result of all this signal conditioning is an AD849x output voltage that is proportional to the temperature at the measurement junction (T_M). The AD849x has the following nominal transfer function.

$$V_{OUT} = (T_M \times 5\ \text{mV/°C}) + V_{REF}$$

For more accuracy, full details on the complete transfer functions of the AD8494/AD8495/AD8496/AD8497 will be provided in the final datasheet.

Input Voltage Protection

The AD849x has very robust inputs. Input voltages can be up to 40 V from the opposite supply rail. For example, with a +5 V positive supply and a −3 V negative supply, the part can safely withstand voltages at the inputs from −35 V to +37 V. Voltage at the reference and sense pins should not go beyond 0.3 V of the supply rails.

RECOMMENDATIONS FOR BEST CIRCUIT PERFORMANCE

Keeping the AD849x at the Same Temperature as the Reference Junction

The AD849x compensates for thermocouple reference junction temperature by using an internal temperature sensor. Any difference in temperature between the AD849x and the reference junction shows up directly as temperature error. Temperature difference may occur if the AD849x is not physically close to the reference junction or if the AD849x is required to supply large amounts of output current, especially on larger supplies.

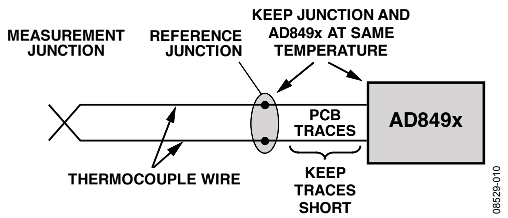

Figure 7. Compensating for Thermocouple Reference Junction Temperature

Driving the Reference Pin

The AD849x comes with a reference pin, which can be used to offset the output voltage. This is particularly useful when reading a negative temperature in a single-supply system.

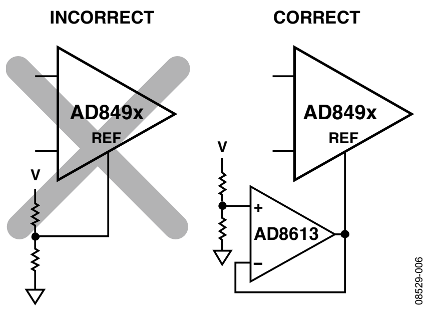

Figure 8. Driving the Reference Pin

For best performance, the reference pin should be driven with a low output impedance source, not a resistor divider. The AD8613 and the OP777 are good choices for the buffer amplifier.

Ground Connection

The thermocouple measurement junction tip determines how the ground should be connected to the thermocouple. The AD849x requires one, and only one, source of common-mode voltage. For thermocouples with insulated tips, a voltage connection (typically ground) must be provided. For thermocouples with grounded or exposed tips, no extra ground connection should be provided: the measurement junction itself sets the common-mode voltage. A ground at the grounded or exposed tip is detrimental to performance, because ground loops can form.

Connecting the ground to the negative input terminal causes the AD849x to rail high in an open thermocouple condition. The AD849x rails low if the ground is connected to the positive input.

If the thermocouple tip type is unknown, a 1 MΩ resistor to ground can be used. This solution works well regardless of whether there is an electrical connection at the measurement junction. If there is no electrical connection at the measurement junction, the resistor is small enough to create a common-mode voltage for the AD849x. If there is an electrical connection, the value is large enough so that any current from the measurement tip to ground is very small, preventing measurement errors.

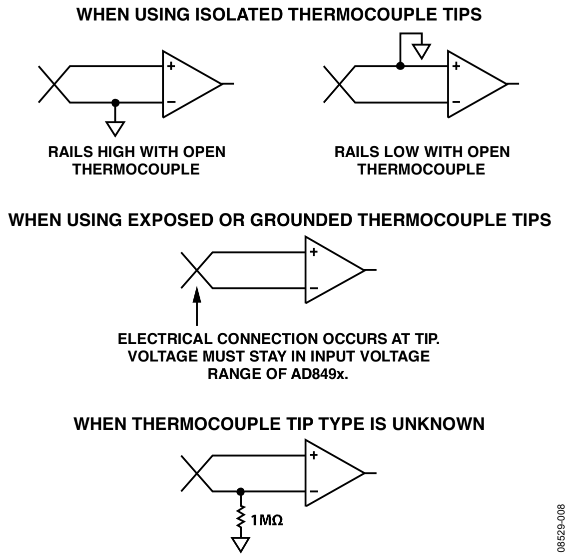

Figure 9. Grounding Options When Using Different Tip Types

Input Filter

A low-pass filter before the input of the AD849x is highly recommended when operating in an electrically noisy environment. Long thermocouple leads can function as an excellent antenna and pick up many unwanted signals.

Figure 10 and Figure 11 show filtering options for different grounding configurations. To prevent input offset currents from influencing the measurement accuracy, resistors should be kept below 50 kΩ.

Although these low-pass filters can filter out noise within the bandwidth of the AD849x, their primary purpose is to filter out noise outside the frequency range of the AD849x. In particular, these filters remove RF signals, which, if allowed to reach the AD849x, could be rectified and appear as temperature fluctuations.

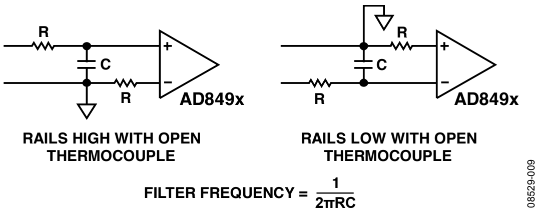

Figure 10. Filter Options for Isolated Thermocouple Tips

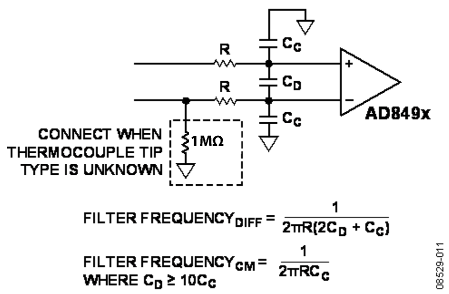

Figure 11. Filter Options for Exposed, Grounded, or Unknown Thermocouple Tips

Thermocouple Nonlinearity

Thermocouples are nonlinear. The AD849x does not compensate for this nonlinearity. This nonlinearity can lead to unacceptable errors, especially at very low or very high temperatures.

When operating near 25°C for the AD8494/AD8495, or near 60°C for the AD8496/AD8497, linearity correction may not be needed. For operation far from these calibration points, linearity correction is recommended.

Thermocouple nonlinearity is typically corrected with a microcontroller in the digital domain.

Debugging Tip

If the AD849x is not providing the expected performance, a useful debugging step is to implement the ambient temperature configuration in Figure 13. If the ambient temperature sensor does not work as expected, the problem is likely with the AD849x or with the downstream circuitry. If the ambient temperature sensor configuration is working correctly, the problem typically lies with how the thermocouple is connected to the AD849x. A common error is an incorrect grounding configuration or lack of filtering.

APPLICATIONS INFORMATION

For the sake of simplicity, the input connections in this section are shown with the negative input grounded and with no other input circuitry. This setup is appropriate for an insulated tip thermocouple in an electrically quiet environment. See the Ground Connection and Input Filter sections for information about additional input circuitry that may be required.

BASIC CONNECTION

Figure 12 shows an example of a basic connection for the AD849x.

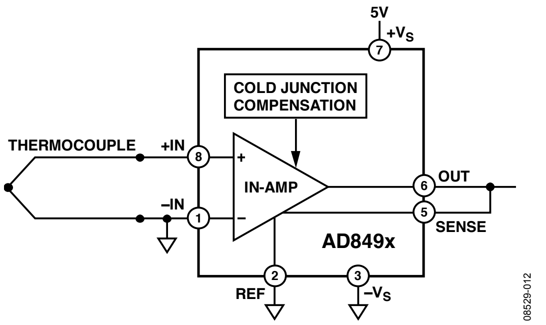

Figure 12. Basic Connection for the AD849x

The SENSE pin should be connected to the output pin of the AD849x. To measure negative temperatures, apply a voltage at the reference pin to offset the output voltage at 0°C.

AMBIENT TEMPERATURE SENSOR

The AD849x can be configured as a standalone Celsius thermometer, as shown in Figure 13. The thermocouple sensing functionality is disabled by shorting both AD849x inputs to ground; the AD849x simply outputs the value from the on-board temperature sensor.

This mode can be particularly useful for debugging a misbehaving circuit. If the basic connection is not working, disconnect the thermocouple and short both inputs to ground. If the system reads the ambient temperature correctly, the problem is related to the thermocouple. If the system does not read the ambient temperature correctly, the problem is with the electronics.

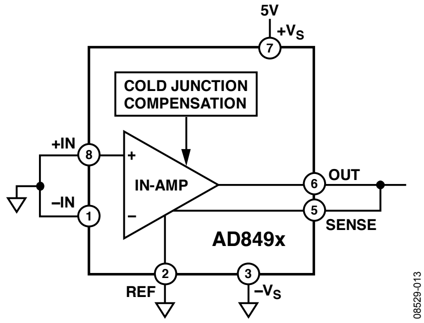

Figure 13. Ambient Temperature Sensor

OUTLINE DIMENSIONS

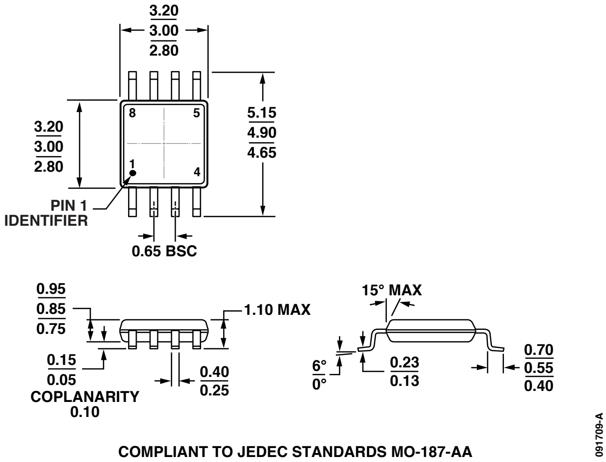

Figure 14. 8-Lead Mini Small Outline Package [MSOP]
(RM-8)
Dimensions shown in millimeters

ORDERING GUIDE

Model[1]	Temperature Range	Package Description	Package Option
AD8494ARMZ	0°C to 50°C	8-Lead MSOP	RM-8
AD8494ARMZ-RL	0°C to 50°C	8-Lead MSOP, 13" Tape and Reel	RM-8
AD8494ARMZ-R7	0°C to 50°C	8-Lead MSOP, 7" Tape and Reel	RM-8
AD8494BRMZ	0°C to 50°C	8-Lead MSOP	RM-8
AD8494BRMZ-RL	0°C to 50°C	8-Lead MSOP, 13" Tape and Reel	RM-8
AD8494BRMZ-R7	0°C to 50°C	8-Lead MSOP, 7" Tape and Reel	RM-8
AD8495ARMZ	0°C to 50°C	8-Lead MSOP	RM-8
AD8495ARMZ-RL	0°C to 50°C	8-Lead MSOP, 13" Tape and Reel	RM-8
AD8495ARMZ-R7	0°C to 50°C	8-Lead MSOP, 7" Tape and Reel	RM-8
AD8495BRMZ	0°C to 50°C	8-Lead MSOP	RM-8
AD8495BRMZ-RL	0°C to 50°C	8-Lead MSOP, 13" Tape and Reel	RM-8
AD8495BRMZ-R7	0°C to 50°C	8-Lead MSOP, 7" Tape and Reel	RM-8
AD8496ARMZ	25°C to 100°C	8-Lead MSOP	RM-8
AD8496ARMZ-RL	25°C to 100°C	8-Lead MSOP, 13" Tape and Reel	RM-8
AD8496ARMZ-R7	25°C to 100°C	8-Lead MSOP, 7" Tape and Reel	RM-8
AD8496BRMZ	25°C to 100°C	8-Lead MSOP	RM-8
AD8496BRMZ-RL	25°C to 100°C	8-Lead MSOP, 13" Tape and Reel	RM-8
AD8496BRMZ-R7	25°C to 100°C	8-Lead MSOP, 7" Tape and Reel	RM-8
AD8497ARMZ	25°C to 100°C	8-Lead MSOP	RM-8
AD8497ARMZ-RL	25°C to 100°C	8-Lead MSOP, 13" Tape and Reel	RM-8
AD8497ARMZ-R7	25°C to 100°C	8-Lead MSOP, 7" Tape and Reel	RM-8
AD8497BRMZ	25°C to 100°C	8-Lead MSOP	RM-8
AD8497BRMZ-RL	25°C to 100°C	8-Lead MSOP, 13" Tape and Reel	RM-8
AD8497BRMZ-R7	25°C to 100°C	8-Lead MSOP, 7" Tape and Reel	RM-8

[1] Z = RoHS Compliant Part.

NOTES

NOTES

Datasheet SHT21P

Humidity and Temperature Sensor IC

- Fully calibrated
- Analog output, PWM interface
- Low power consumption
- Excellent long term stability
- DFN type package – reflow solderable

Product Summary

SHT21P, the new humidity and temperature sensor of Sensirion is about to set new standards in terms of size and intelligence: Embedded in a reflow solderable Dual Flat No leads (DFN) package of 3 x 3mm foot print and 1.1mm height it provides calibrated, linearized signals in analog Pulse Width Modulated (PWM) format.

With a completely new designed CMOSens® chip, a reworked capacitive type humidity sensor and an improved band gap temperature sensor the performance level has been lifted even beyond the outstanding reliability level of the previous sensor generation (SHT1x and SHT7x). For example, measures have been taken to stabilize the behavior at high humidity levels.

PWM signal runs on a base frequency of 120Hz, the data signal is provided on SDA line. Pulling SCL high or low allows for switching between humidity and temperature, respectively. The sensor measures twice per second. The PWM signal may be converted to an analog ratiometric interface by adding a low pass filter.

Every sensor is individually calibrated and tested. Lot identification is printed on the sensor.

With made improvements and the miniaturization of the sensor the performance-to-price ratio has been improved. SHT21 is also available with digital I²C or SDM interface.

Dimensions

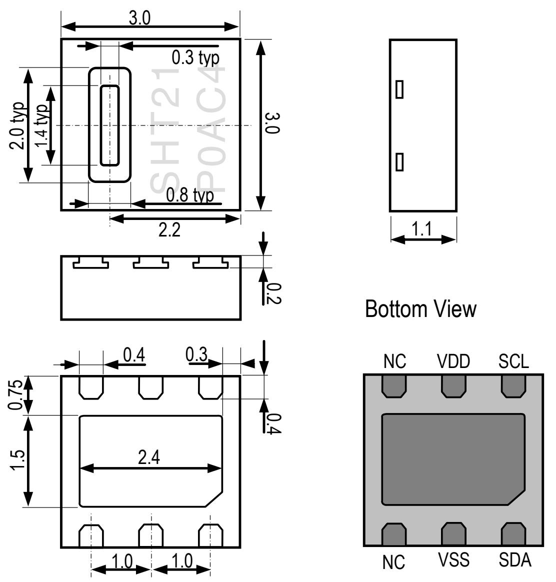

Figure 1: Drawing of SHT21P sensor package, dimensions are given in mm (1mm = 0.039inch), tolerances are ±0.1mm. The die pad (center pad) is internally connected to VSS. The NC pads must be left floating. Numbering of E/O pads starts at lower right corner (indicated by notch in die pad) and goes clockwise (compare Table 2).

Sensor Chip

SHT21P features a generation 4C CMOSens® chip. Besides the capacitive relative humidity sensor and the band gap temperature sensor, the chip contains an amplifier, A/D converter, OTP memory and a digital processing unit.

Material Contents

While the sensor itself is made of Silicon the sensors' housing consists of a plated Cu lead-frame and green epoxy-based mold compound. The device is free of Pb, Cd and Hg – hence it is fully RoHS and WEEE compliant.

Additional Information

Additional information such as Application Notes is available from the web page www.sensirion.com/sht21. For more information please contact Sensirion via info@sensirion.com.

Sensor Performance

Relative Humidity

Parameter	Condition	min	typ	max	Units
Resolution	12 bit		0.04		%RH
Accuracy tolerance [1]	typ		±2.0		%RH
	max	see Figure 2			%RH
Repeatability			±0.1		%RH
Hysteresis			±1		%RH
Nonlinearity			<0.1		%RH
Response time [2]	τ 63%		8		s
Operating Range	extended [3]	0		100	%RH
Long Term Drift [4]	normal		< 0.5		%RH/yr

Temperature

Parameter	Condition	min	typ	max	Units
Resolution	14 bit		0.01		°C
Accuracy tolerance [1]	typ		±0.3		°C
	max	see Figure 3			°C
Repeatability			±0.1		°C
Operating Range	extended [3]	-40		125	°C
Response Time [6]	τ 63%	5		30	s
Long Term Drift			< 0.04		°C/yr

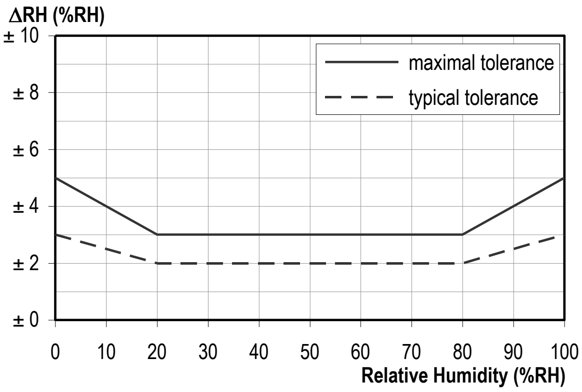

Figure 2 Typical and maximal tolerance at 25°C for relative humidity. For extensive information see Users Guide, Sect. 1.2.

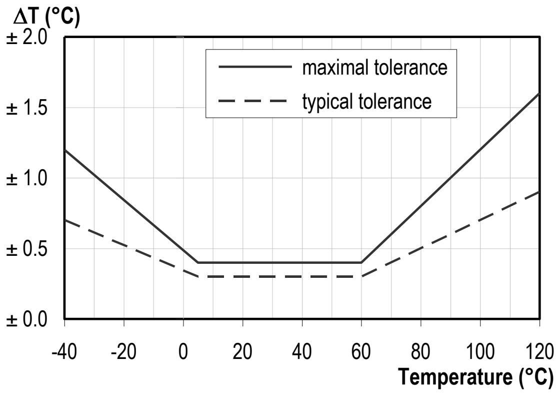

Figure 3 Typical and maximal temperature accuracy tolerance

Electrical Specification

Parameter	Condition	min	typ	max	Units
Supply Voltage, VDD		2.1	3.0	3.6	V
Supply Current, IDD [5]			180		µA
Power Dissipation [5]			0.54		mW
PWM frequency	40 °C	108	120	132	Hz
Temperature drift of PWM frequency		-0.07		-0.12	Hz/°C
Measurement Frequency			2		Hz
Switch RH/T on SDA	SCL up → RH; SCL down → T				

Table 1 Electrical specification. For absolute maximum values see Chapter 4.1 of Users Guide.

Packaging Information

Sensor Type	Packaging	Quantity	Order Number
SHT21P	Tape & Reel	400	1-100711-01
	Tape & Reel	1500	1-100700-01
	Tape & Reel	5000	1-100699-01

This datasheet is subject to change and may be amended without prior notice.

1 Accuracies are tested at Outgoing Quality Control at 25°C and 3.0V. Values exclude hysteresis and long term drift and are applicable to non-condensing environments only.

2 Time for achieving 63% of a step function, valid at 25°C and 1 m/s airflow.

3 Normal operating range: 0-80%RH, beyond this limit sensor may read a reversible offset with slow kinetics (+3%RH after 60h at humidity >80%RH). For more details please see Section 1.1 of the Users Guide.

4 Value may be higher in environments with vaporized solvents, out-gassing tapes, adhesives, packaging materials, etc. For more details please refer to Handling Instructions.

5 Values of Supply Current and Power Dissipation are based upon fixed VDD = 3.0V and T = 25°C.

6 Response time depends on heat conductivity of sensor substrate.

Users Guide SHT21P

1 Extended Specifications

For details on how Sensirion is specifying and testing accuracy performance please consult Application Note “Statement on Sensor Specification”.

1.1 Operating Range

The sensor works stable within recommended Normal Range – see Figure 4. Long term exposure to conditions outside Normal Range, especially at humidity >80%RH, may temporarily offset the RH signal (+3%RH after 60h). After return into the Normal Range it will slowly return towards calibration state by itself. See Section 2.3 “Reconditioning Procedure” for eliminating the offset. Prolonged exposure to extreme conditions may accelerate ageing.

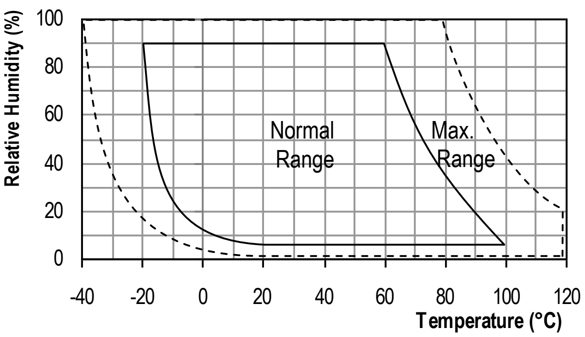

Figure 4 Operating Conditions

1.2 RH accuracy at various temperatures

Maximal tolerance for RH accuracy at 25°C is defined in Figure 2. For other temperatures maximal tolerance has been evaluated to be within limits displayed in Figure 5.

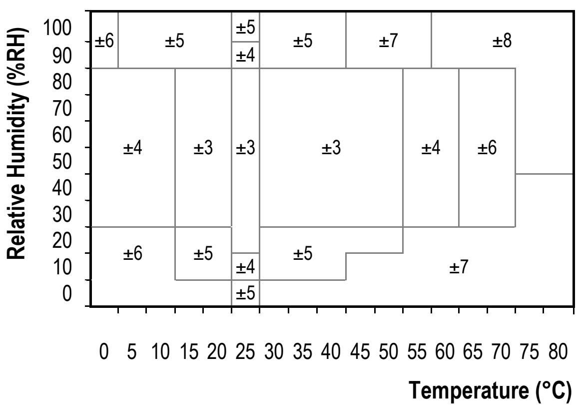

Figure 5 Maximal tolerance of relative humidity measurements given in %RH for temperatures 0 – 80°C.

Please note that above values are maximal tolerances (not including hysteresis) against a high precision reference such as a dew point mirror. Typical deviations are at ±2%RH where maximal tolerance is ±3%RH and about half the maximal tolerance at other values.

2 Application Information

2.1 Soldering Instructions

The *DFN’s die pad* (centre pad) and *perimeter I/O pads* are fabricated from a planar copper lead-frame by over-molding leaving the die pad and I/O pads exposed for mechanical and electrical connection. Both the I/O pads and die pad should be soldered to the PCB. In order to prevent oxidation and optimize soldering, the bottom side of the sensor pads is plated with Ni/Pd/Au.

On the PCB the *I/O lands*[7] should be 0.2mm longer than the package I/O pads. Inward corners may be rounded to match the I/O pad shape. The I/O land width should match the DFN-package I/O-pads width 1:1 and the land for the die pad should match 1:1 with the DFN package – see Figure 6.

The *solder mask*[8] *design* for the land pattern preferably is of type Non-Solder Mask Defined (NSMD) with solder mask openings larger than metal pads. For NSMD pads, the solder mask opening should be about 120µm to 150µm larger than the pad size, providing a 60µm to 75µm design clearance between the copper pad and solder mask. Rounded portions of package pads should have a matching rounded solder mask-opening shape to minimize the risk of solder bridging. For the actual pad dimensions, each pad on the PCB should have its own solder mask opening with a web of solder mask between adjacent pads.

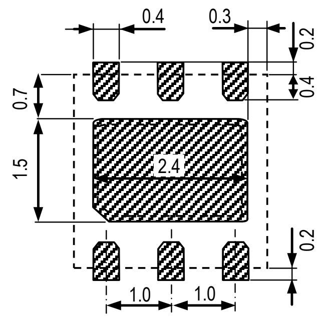

Figure 6 Recommended metal land pattern for SHT2x. Values in mm. Die pad (centre pad) may be left floating or be connected to ground, NC pads shall be left floating. The outer dotted line represents the outer dimension of the DFN package.

[7] The land pattern is understood to be the metal layer on the PCB, onto which the DFN pads are soldered to.

[8] The solder mask is understood to be the insulating layer on top of the PCB covering the connecting lines.

For *solder paste printing* a laser-cut, stainless steel stencil with electro-polished trapezoidal walls and with 0.125mm stencil thickness is recommended. For the I/O pads the stencil apertures should be 0.1mm longer than PCB pads and positioned with 0.1mm offset away from the centre of the package. The die pad aperture should cover about 70 – 90% of the pad area – say up to 1.4mm x 2.3mm centered on the thermal land area. It can also be split in two openings.

Due to the low mounted height of the DFN, "no clean" type 3 solder paste[9] is recommended as well as Nitrogen purge during reflow.

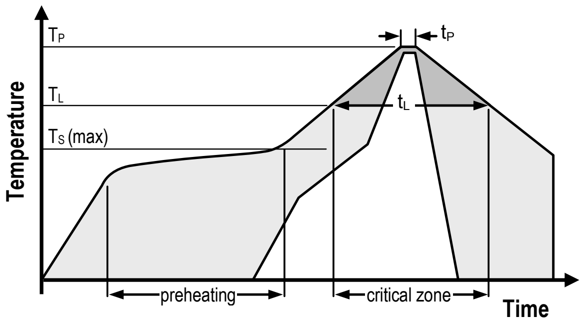

Figure 7 Soldering profile according to JEDEC standard. T_P <= 260°C and t_P < 30sec for Pb-free assembly. T_L < 220°C and t_L < 150sec. Ramp-up/down speeds shall be < 5°C/sec.

It is important to note that the diced edge or side faces of the I/O pads may oxidise over time, therefore a solder fillet may or may not form. Hence there is no guarantee for solder joint fillet heights of any kind.

For soldering SHT2x, standard *reflow soldering* ovens may be used. The sensor is qualified to withstand soldering profile according to IPC/JEDEC J-STD-020 with peak temperatures at 260°C during up to 30sec for Pb-free assembly in IR/Convection reflow ovens (see Figure 7).

For manual soldering contact time must be limited to 5 seconds at up to 350°C.

IMPORTANT: After soldering, the devices should be stored at >75%RH for at least 12h to allow the sensor element to re-hydrate. Otherwise the sensor may read an offset that slowly disappears if exposed to ambient conditions. Alternatively the re-hydration process may be performed at ambient conditions (>40%RH) during more than 5 days.

In no case, neither after manual nor reflow soldering, a board wash shall be applied. Therefore, and as mentioned above, it is strongly recommended to use "no-clean" solder paste. In case of applications with exposure of the sensor to corrosive gases or condensed water (i.e. environments with high relative humidity) the soldering pads shall be sealed (e.g. conformal coating) to prevent loose contacts or short cuts.

2.2 Storage Conditions and Handling Instructions

Moisture Sensitivity Level (MSL) is 1, according to IPC/JEDEC J-STD-020. At the same time, it is recommended to further process the sensors within 1 year after date of delivery.

It is of great importance to understand that a humidity sensor is not a normal electronic component and needs to be handled with care. Chemical vapors at high concentration in combination with long exposure times may offset the sensor reading.

For this reason it is recommended to store the sensors in original packaging including the sealed ESD bag at following conditions: Temperature shall be in the range of 10°C – 50°C and humidity at 20 – 60%RH (sensors that are not stored in ESD bags). For sensors that have been removed from the original packaging we recommend to store them in ESD bags made of metal-in PE-HD[10].

In manufacturing and transport the sensors shall be prevented of high concentration of chemical solvents and long exposure times. Out-gassing of glues, adhesive tapes and stickers or out-gassing packaging material such as bubble foils, foams, etc. shall be avoided. Manufacturing area shall be well ventilated.

For more detailed information please consult the document *"Handling Instructions"* or contact Sensirion.

2.3 Reconditioning Procedure

As stated above extreme conditions or exposure to solvent vapors may offset the sensor. The following reconditioning procedure may bring the sensor back to calibration state:

Baking:	100 – 105°C at < 5%RH for 10h
Re-Hydration:	20 – 30°C at ~ 75%RH for 12h [11].

2.4 Temperature Effects

Relative humidity reading strongly depends on temperature. Therefore, it is essential to keep humidity sensors at the same temperature as the air of which the relative humidity is to be measured. In case of testing or qualification the reference sensor and test sensor must show equal temperature to allow for comparing humidity readings.

If the sensor shares a PCB with electronic components that produce heat it should be mounted in a way that prevents heat transfer or keeps it as low as possible. Measures to reduce heat transfer can be ventilation, reduction of copper layers between the sensor and the

[9] Solder types are related to the solder particle size in the paste: Type 3 covers the size range of 25 – 45 µm (powder type 42).

[10] For example, 3M antistatic bag, product "1910" with zipper.

[11] 75%RH can conveniently be generated with saturated NaCl solution.

rest of the PCB or milling a slit into the PCB around the sensor – see Figure 8.

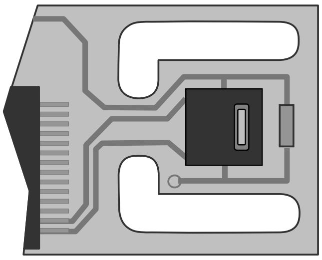

Figure 8 Top view of example of mounted SHT2x with slits milled into PCB to minimize heat transfer.

2.5 Light

The SHT2x is not light sensitive. Prolonged direct exposure to sunshine or strong UV radiation may age the sensor.

2.6 Materials Used for Sealing / Mounting

Many materials absorb humidity and will act as a buffer increasing response times and hysteresis. Materials in the vicinity of the sensor must therefore be carefully chosen. Recommended materials are: Any metals, LCP, POM (Delrin), PTFE (Teflon), PEEK, PP, PB, PPS, PSU, PVDF, PVF.

For sealing and gluing (use sparingly): Use high filled epoxy for electronic packaging (e.g. glob top, underfill), and Silicone. Out-gassing of these materials may also contaminate the sensor (see Section 2.2). Therefore try to add the sensor as a last manufacturing step to the assembly, store the assembly well ventilated after manufacturing or bake at >50°C for 24h to outgas contaminants before packing.

Interface Specifications

Pin	Name	Comment
1	SDA	Data bit-stream
2	VSS	Ground
5	VDD	Supply Voltage
6	SCL	Selector for RH or T
3,4	NC	Not connected

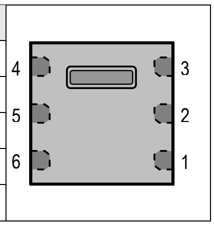

Table 2 SHT21P pin assignment (top view)

2.7 Power Pins (VDD, VSS)

The supply voltage of SHT21P must be in the range of 2.1 – 3.6V, recommended supply voltage is 3.0V. Power supply pins Supply Voltage (VDD) and Ground (VSS) must be decoupled with a 100nF capacitor, that shall be placed as close to the sensor as possible – see Figure 9.

2.8 SCL – Output Selector Pad

SCL is used to select humidity or temperature output. SCL high yields humidity output, SCL low yields temperature output. Please note that a change of SCL will affect the output on SDA after maximal 1.2 seconds.

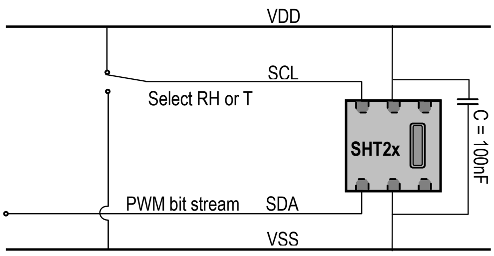

Figure 9 Typical application circuit, including decoupling of VDD and VSS by a capacitor.

2.9 SDA – Bit Stream Pad

On SDA the sensor is providing PWM output. The signal is carrying humidity or temperature data depending on SCL being high or low, respectively. See Table 4 for detailed I/O characteristic of the sensor.

3 Electrical Characteristics

3.1 Absolute Maximum Ratings

The electrical characteristics of SHT21P are defined in Table 1. The absolute maximum ratings as given in Table 3 are stress ratings only and give additional information. Functional operation of the device at these conditions is not implied. Exposure to absolute maximum rating conditions for extended periods may affect the sensor reliability (e.g. hot carrier degradation, oxide breakdown).

Parameter	min	max	Units
VDD to VSS	-0.3	5	V
Digital IO Pins (SDA, SCL) to VSS	-0.3	VDD + 0.3	V
Input Current on any Pin	-100	100	mA

Table 3 Electrical absolute maximum ratings

ESD immunity is qualified according to JEDEC JESD22-A114 method (Human Body Model at ±4kV), JEDEC JESD22-A115 method (Machine Model ±200V) and ESDA ESD-STM5.3.1-1999 and AEC-Q100-011 (Charged Device Model, 750V corner pins, 500V other pins). Latch-up immunity is provided at a force current of ±100mA with T_{amb} = 125°C according to JEDEC JESD78. For exposure beyond named limits the sensor needs additional protection circuit.

3.2 Input / Output Characteristics

The electrical characteristics such as power consumption, low and high level input and output voltages depend on the supply voltage. For proper communication with the sensor it is essential to make sure that signal design is strictly within the limits given in Table 4.

Parameter	min	typ	max	Units
Output Low Voltage, VOL		0		V
Output High Voltage, VOH		VDD		V
Output Sink Current, IOL			40	µA

Table 4 DC characteristics of output pad. VDD = 2.1 V to 3.6 V, T = -40 °C to 125 °C, unless otherwise noted.

4 Communication with Sensor

4.1 Start up Sensor

As a first step, the sensor is powered up to VDD (between 2.1V and 3.6V). After power-up, the sensor needs at most 150ms for reaching idle state. During that time SDA is in undefined state. Then the sensor starts measuring and providing data on PWM bit-stream.

4.2 PWM Specification

Pulse Width Modulation runs on a constant frequency and the measured information is provided as duty cycle on that frequency – see Figure 10. Such information is measured humidity for SCL pulled high and temperature for SCL pulled low.

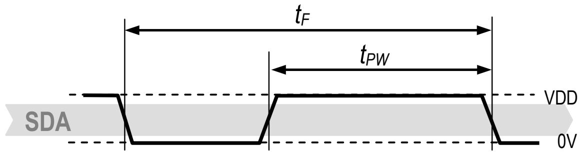

Figure 10 PWM signal. Base frequency runs constantly at approximately 120 Hz, hence t_F is about 8.3ms. The signal is provided on t_{PW} as a ratio of t_F.

The measured data – either humidity or temperature – is provided as ratio of t_{PW} and t_F. t_{PW} shall always be given as ratio of t_F to make it independent of variations of the base frequency.

5 Conversion of Signal Output

Resolution is set to 10 bit relative humidity and 12 bit temperature reading and cannot be changed. The sensor reading is linear and hence it can be converted to a physical value by an easy linear equation.

5.1 Relative Humidity Conversion

With the relative humidity signal output the relative humidity *RH* is obtained by the following formula (result in %RH):

$$RH = -6 + 125 \cdot \frac{t_{PW}}{t_F}$$

The physical value *RH* given above corresponds to the relative humidity above liquid water according to World Meteorological Organization (WMO). For relative humidity values above ice RH_i the values need to be transformed as from relative humidity above water RH_w at a certain temperature *t* follows – compare also Application Note “Introduction to Humidity”:

$$RH_i = RH_w \cdot exp\left(\frac{\beta_w \cdot t}{\lambda_w + t}\right) \Big/ exp\left(\frac{\beta_i \cdot t}{\lambda_i + t}\right)$$

Units are %RH for relative humidity and °C for temperature. The corresponding coefficients are defined as follows: β_w = 17.62, λ_w = 243.12°C, β_i = 22.46, λ_i = 272.62°C.

5.2 Temperature Conversion

The temperature *T* is calculated by inserting the ratio of t_{PW} and t_F into the following formula (result in °C):

$$T = -46.85 + 175.72 \cdot \frac{t_{PW}}{t_F}$$

6 Environmental Stability

The SHT2x sensor series were tested based on AEC-Q100 Rev. G qualification test method where applicable. Sensor specifications are tested to prevail under the AEC-Q100 temperature grade 2 test conditions listed in Table 9[12]. Sensor performance under other test conditions cannot be guaranteed and is not part of the sensor specifications. Especially, no guarantee can be given for sensor performance in the field or for customer's specific application.

Environment	Standard	Results[13]
HTOL	125°C, 408 hours	Within specifications
TC	-50°C - 125°C, 1000 cycles	Within specifications
UHST	130°C / 85%RH / ≈2.3bar, 96h	Within specifications
THB	85°C / 85%RH, 1000h	Within specifications
ESD immunity	HBM ±4kV, MM ±200V, CDM 750V/500V (corner/other pins)	Qualified
Latch-up	force current of ±100mA with T_{amb} = 125°C	Qualified

Table 5: Qualification tests: HTOL = High Temperature Operating Lifetime, TC = Temperature Cycles, UHST = Unbiased Highly accelerated Stress Test, THB = Temperature Humidity Biased. For details on ESD see Sect. 4.1.

If sensors are qualified for reliability and behavior in extreme conditions, please make sure that they experience same conditions as the reference sensor. It should be taken into account that response times in assemblies may be longer, hence enough dwell time for the measurement shall be granted. For detailed information please consult Application Note "Qualification Guide".

7 Packaging

7.1 Packaging Type

SHT2x sensors are provided in DFN packaging (in analogy with QFN packaging). DFN stands for Dual Flat No leads.

The sensor chip is mounted to a lead frame made of Cu and plated with Ni/Pd/Au. Chip and lead frame are over molded by green epoxy-based mold compound. Please note that side walls of sensors are diced and hence lead frame at diced edge is not covered with respective protective coating. The total weight of the sensor is 25mg.

[12] Sensor operation temperature range is -40 to 105°C according to AEC-Q100 temperature grade 2.

[13] According to accuracy and long term drift specification given on Page 2.

7.2 Filter Cap and Sockets

For SHT2x a filter cap SF2 is available. It is designed for fast response times and compact size. Please find the datasheet on Sensirion's web page.

For testing of SHT2x sensors sockets, such as from Plastronics, part number 10LQ50S13030 are recommended (see e.g. www.locknest.com).

7.3 Traceability Information

All SHT21 are laser marked with an alphanumeric, five-digit code on the sensor – see Figure 11.

Figure 11 Laser marking on sensor. For details see text.

The marking on the sensor consists of two lines with five digits each. The first line denotes the sensor type (SHT21). The first digit of the second line defines the output mode (D = digital, Sensibus and I2C, P = PWM, S = SDM). The second digit defines the manufacturing year (0 = 2010, 1 = 2011, etc.). The last three digits eventually represent an alphanumeric tracking code. That code can be decoded by Sensirion only and allows for tracking on batch level through production, calibration and testing – and will be provided upon justified request.

Reels are also labeled, as displayed in Figure 12 and Figure 13, and give additional traceability information.

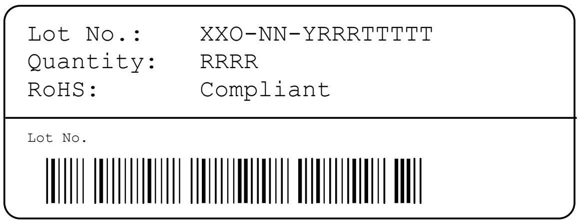

Figure 12: First label on reel: XX = Sensor Type (21 for SHT21), O = Output mode (D = Digital, P = PWM, S = SDM), NN = product revision no., Y = last digit of year, RRR = number of sensors on reel divided by 10 (200 for 2000 units), TTTTT = Traceability Code.

SENSIRION
THE SENSOR COMPANY

Device Type:	1-100PPP-NN
Description:	Humidity & Temperature Sensor SHTxx
Part Order No.	1-100PPP-NN or Customer Number
Date of Delivery:	DD.MM.YYYY
Order Code:	46CCCC / 0

Figure 13: Second label on reel: For Device Type and Part Order Number (See Packaging Information on page 2), Delivery Date (also Date Code) is date of packaging of sensors (DD = day, MM = month, YYYY = year), CCCC = Sensirion order number.

7.4 Shipping Package

SHT2x are provided in tape & reel shipment packaging, sealed into antistatic ESD bags. For SHT21P standard packaging sizes are 400, 1500 and 5000 units per reel. Each reel contains 440mm (55 pockets) header tape and 200mm (25 pockets) trailer tape.

The drawing of the packaging tapes with sensor orientation is shown in Figure 13. The reels are provided in sealed antistatic bags.

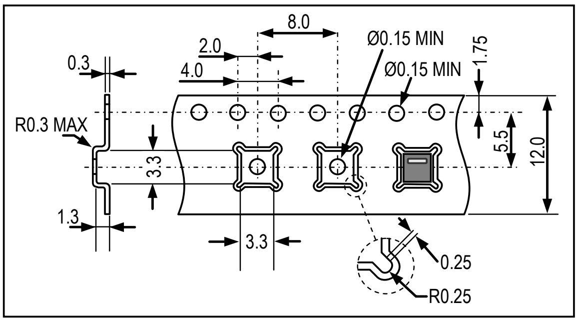

Figure 14 Sketch of packaging tape and sensor orientation. Header tape is to the right and trailer tape to the left on this sketch.

Revision History

Date	Version	Page(s)	Changes
19 Aug 2009	0.6	1, 6	Figure 1 adapted, add details to Section 1.2, 5.1 and Chapter 7
29 Jan 2010	1.0	1 – 9	Completely revised version. Require Change Protocol for details.
5 May 2010	1.1	1 – 9	Elimination of errors and addition of information (ask for change protocol)
31 May 2011	2	1 – 4, 6 – 10	Updated temperature accuracy specifications, MSL and standards. Elimination of errors. For detailed information, please require complete change list at info@sensirion.com.
December 2011	3	1, 7	Minor text adaptations and corrections.

Important Notices

Warning, Personal Injury

Do not use this product as safety or emergency stop devices or in any other application where failure of the product could result in personal injury. Do not use this product for applications other than its intended and authorized use. Before installing, handling, using or servicing this product, please consult the data sheet and application notes. Failure to comply with these instructions could result in death or serious injury.

If the Buyer shall purchase or use SENSIRION products for any unintended or unauthorized application, Buyer shall defend, indemnify and hold harmless SENSIRION and its officers, employees, subsidiaries, affiliates and distributors against all claims, costs, damages and expenses, and reasonable attorney fees arising out of, directly or indirectly, any claim of personal injury or death associated with such unintended or unauthorized use, even if SENSIRION shall be allegedly negligent with respect to the design or the manufacture of the product.

ESD Precautions

The inherent design of this component causes it to be sensitive to electrostatic discharge (ESD). To prevent ESD-induced damage and/or degradation, take customary and statutory ESD precautions when handling this product.
See application note "ESD, Latchup and EMC" for more information.

Warranty

SENSIRION warrants solely to the original purchaser of this product for a period of 12 months (one year) from the date of delivery that this product shall be of the quality, material and workmanship defined in SENSIRION's published specifications of the product. Within such period, if proven to be defective, SENSIRION shall repair and/or replace this product, in SENSIRION's discretion, free of charge to the Buyer, provided that:

- notice in writing describing the defects shall be given to SENSIRION within fourteen (14) days after their appearance;
- such defects shall be found, to SENSIRION's reasonable satisfaction, to have arisen from SENSIRION's faulty design, material, or workmanship;
- the defective product shall be returned to SENSIRION's factory at the Buyer's expense; and
- the warranty period for any repaired or replaced product shall be limited to the unexpired portion of the original period.

This warranty does not apply to any equipment which has not been installed and used within the specifications recommended by SENSIRION for the intended and proper use of the equipment. EXCEPT FOR THE WARRANTIES EXPRESSLY SET FORTH HEREIN, SENSIRION MAKES NO WARRANTIES, EITHER EXPRESS OR IMPLIED, WITH RESPECT TO THE PRODUCT. ANY AND ALL WARRANTIES, INCLUDING WITHOUT LIMITATION, WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE, ARE EXPRESSLY EXCLUDED AND DECLINED.
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SENSIRION does not assume any liability arising out of any application or use of any product or circuit and specifically disclaims any and all liability, including without limitation consequential or incidental damages. All operating parameters, including without limitation recommended parameters, must be validated for each customer's applications by customer's technical experts. Recommended parameters can and do vary in different applications.
SENSIRION reserves the right, without further notice, (i) to change the product specifications and/or the information in this document and (ii) to improve reliability, functions and design of this product.

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www.sensirion.com.cn

To find your local representative, please visit www.sensirion.com/contact

T-41-39

LM020L
LM020LN (EL Backlit Version)

- 16 character x 1 line
- Controller LSI HD44780 is built-in (See page 115).
- +5V single power supply

MECHANICAL DATA (Nominal dimensions)

Module size .... 80W x 36H x 12T (max.) mm
Effective display area .... 64.5W x 13.8H mm
Character size (5 x 7 dots) .... 3.07W x 5.73H mm
Characrer pitch .... 3.77 mm
Dot size .... 0.55W x 0.75H mm
Weight .... about 25 g

ABSOLUTE MAXIMUM RATINGS

	min.	max.
Power supply for logic ($V_{DD}-V_{SS}$)	0	7.0 V
Power supply for LCD drive ($V_{DD}-V_O$)	0	13.5 V
Input voltage (Vi)	V_{SS}	V_{DD} V
Operating temperature (Ta)	0	50°C
Storage temperature (Tstg)	−20	70°C

EL Power Supply (when fitted)
Voltage (VEL) .... AC 150 Vms
Frequency (fEL) (at 100 Vms) 1kHz

ELECTRICAL CHARACTERISTICS

Ta = 25°C, V_{DD} = 5.0 V ± 0.25 V

Input "high" voltage (Vi_H) .... 2.2 V min.
Input "low" voltage (Vi_L) .... 0.6 V max.
Output high voltage (V_{OH}) ($-I_{OH}$ = 0.2 mA) . 2.4 V min.
Output low voltage (V_{OL}) (I_{OL} = 1.2 mA) ... 0.4 V max.
Power supply current (I_{DD}) (V_{DD} = 5.0 V) .. 1.0 mA typ.
2.0 mA max.

Power supply for LCD drive (Recommended) ($V_{DD}-V_O$)
Duty = 1/16
Range of $V_{DD}-V_O$ .... 1.5~5.25 V
Ta = 0°C .... 4.6 V typ.
Ta = 25°C .... 4.4 V typ.
Ta = 50°C .... 4.2 V typ.

Power Supply for EL (when fitted)
VEL (typ. at 400Mz) .... 100 Vms
fEL (max at VEL 100V, fEL 400Hz) 9.5mA

OPTICAL DATA .... See page 5.

INTERNAL PIN CONNECTION

Pin No.	Symbol	Level	Function	
1	V_{SS}	–	0V	Power supply
2	V_{DD}	–	+5V	
3	V_O	–	–	
4	RS	H/L	L: Instruction code input H: Data input	
5	R/W	H/L	H: Data read (LCD module→MPU) L: Data write (LCD module←MPU)	
6	E	H, H→L	Enable signal	
7	DB0	H/L	Data bus line Note (1), (2)	
8	DB1	H/L		
9	DB2	H/L		
10	DB3	H/L		
11	DB4	H/L		
12	DB5	H/L		
13	DB6	H/L		
14	DB7	H/L		

Luminescent output of EL (where fitted) at Ø = 25°C, Ø = 0°C - 6cd / m^2 typ.

Notes:

In the HD44780, the data can be sent in either 4-bit 2-operation or 8-bit 1-operation so that it can interface to both 4 and 8 bit MPU's.

(1) When interface data is 4 bits long, data is transferred using only 4 buses of DB_4~DB_7 and DB_0~DB_3 are not used. Data transfer between the HD44780 and the MPU completes when 4-bit data is transferred twice. Data of the higher order 4 bits (contents of DB_4~DB_7 when interface data is 8 bits long) is transferred first and then lower order 4 bits (contents of DB_0~DB_3 when interface data is 8 bits long).

(2) When interface data is 8 bits long, data is transferred using 8 data buses of DB_0~DB_7.

DRIVING INFORMATION

To reduce component count, this module is configured as a 2 line of 8 character display but with these organised to visually appear as 1 line of 16 characters.

The consequences are :

1) on power up this must be configured as 2 line display
2) character address not continuous 0 - 7 address is 00HEX - 07HEX, 8 - 15 address is 40HEX - 47HEX

Unit: mm

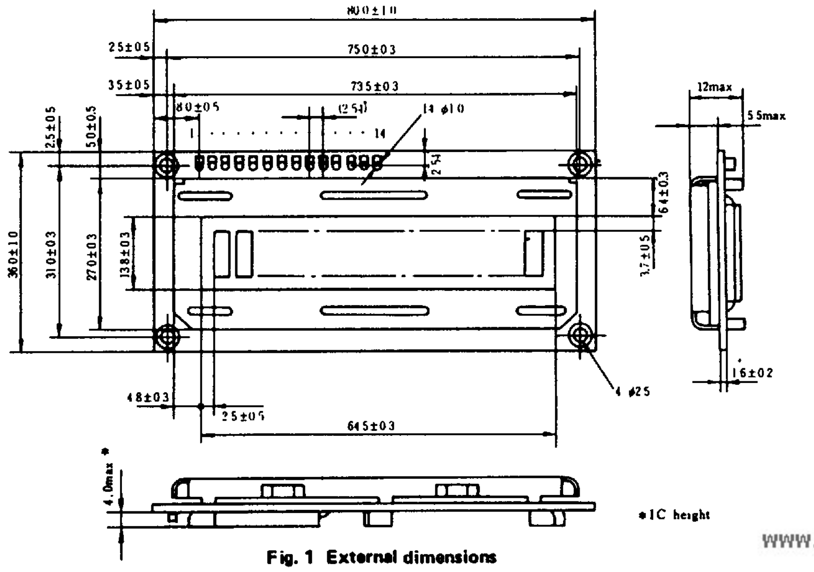


Fig. 1 External dimensions

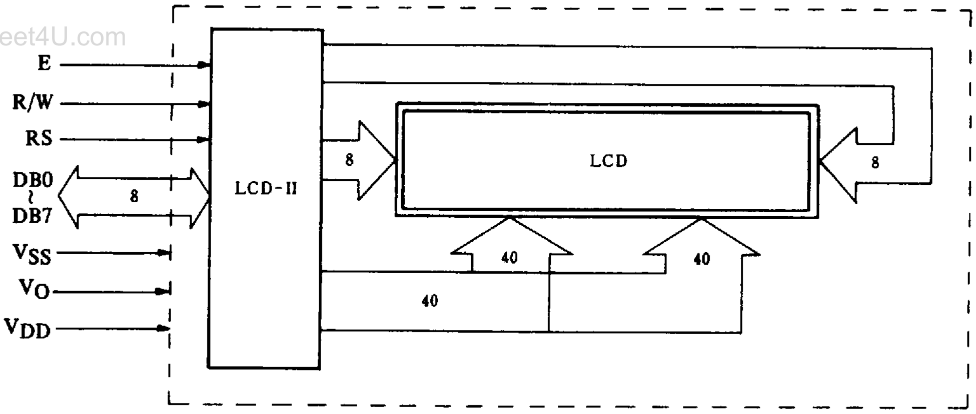
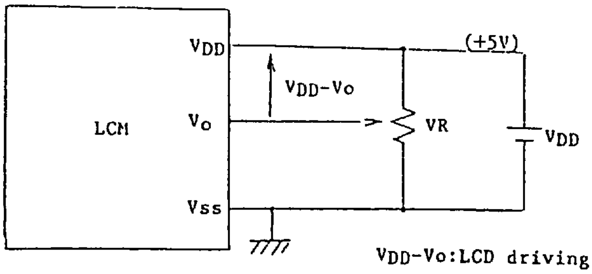


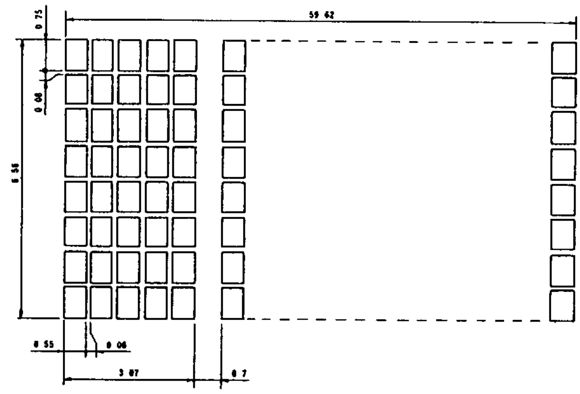
Fig. 2 Block diagram

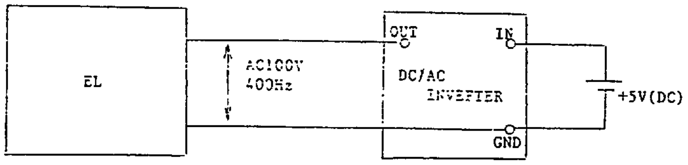


VDD-Vo:LCD driving voltage

VR:10k 20k

POWER SUPPLY for LCM

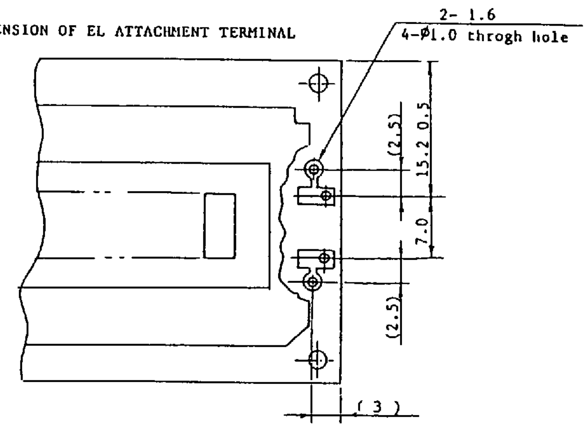




Recommended DC/AC INVERTER : NEL-D32- 45
(Made by NEC)

POWER SUPPLY for EL

DIMENSION OF EL ATTACHMENT TERMINAL



TIMING CHARACTERISTICS

Item	Symbol	Test condition	Min.	Typ.	Max.	Unit
Enable cycle time	t_{cyc}	Fig. 5, Fig. 6	1.0	–	–	μs
Enable pulse width	PW_{EH}	Fig. 5, Fig. 6	450	–	–	ns
Enable rise/fall time	t_{Er}, t_{Ef}	Fig. 5, Fig. 6	–	–	25	ns
RS, R/W set up time	t_{AS}	Fig. 5, Fig. 6	140	–	–	ns
Data delay time	t_{DDR}	Fig. 6	–	–	320	ns
Data set up time	t_{DSW}	Fig. 5	195	–	–	ns
Hold time	t_H	Fig. 5, Fig. 6	20	–	–	ns

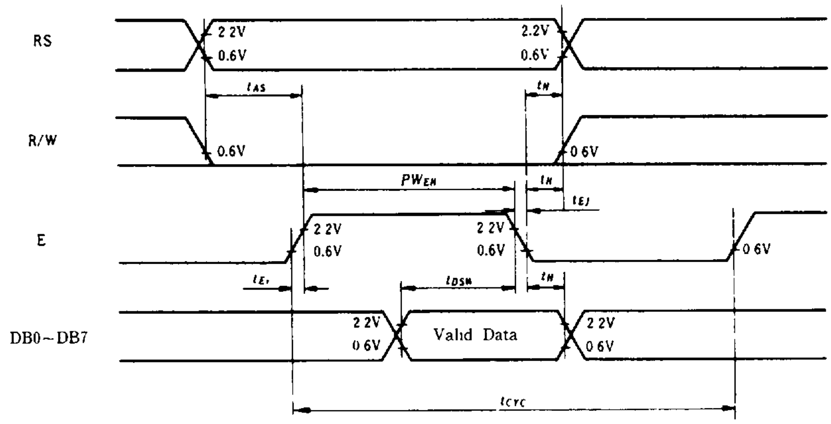


Fig. 5 Interface timing (data write)

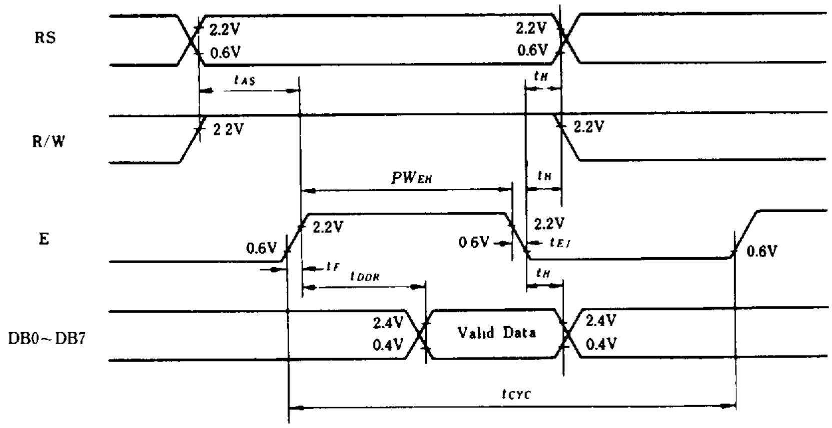


Fig. 6 Interface timing (data read)