HY11P13
IR Measurement
Application Note

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1 Brief Introduction

Common applications of infrared sensors are in medical, industrial, and consumer fields, such as ear thermometers, forehead thermometers, industrial temperature instrument, infrared thermometer…etc. In the application of ear thermometer, it is necessary to pay attention on the warming effect while inserting the ear, connection of wave guide and sensor...etc. As for the application of infrared thermometer, distances of the lens to object,and the lens focal distance should be noticed. The main purpose of this article is to illustrate how to use HY11P13 designed by HYCON Technology Corp. to measure electrical signals converted by sensor.

2 Theory Explanation

2.1 Introduction of Infrared Wavelength

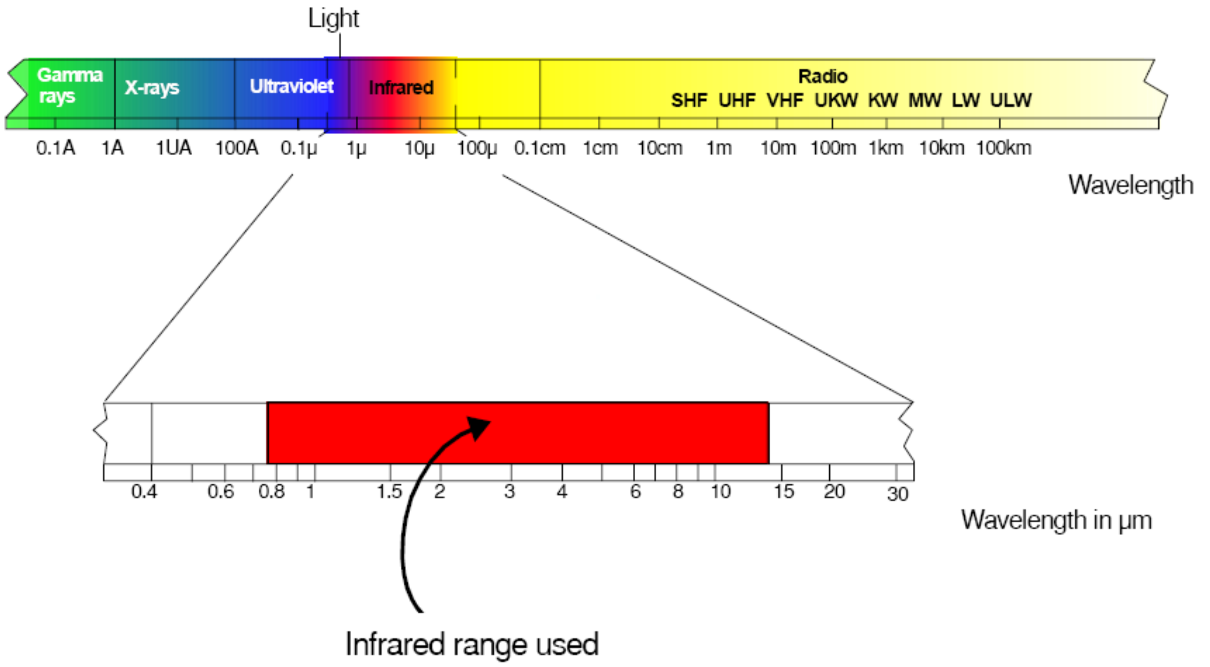


Figure 1 Wavelength Spectrum Map, Infrared Common Measurement Wavelength Range：700nm~14000nm [1]

According to infrared wavelength and radiant, there are 3 classifications as below.

Near Infra-red, NIR: 700~2,000nm

Middle Infra-red, MIR: 3,000~5,000nm

Far Infra-red, FIR: 8,000~14,000nm

2.2 Objects Radiation

Due to the diversity of strips, the discussion of this article is based on Equivalent Circuit. Before kicking off new project, it is necessary to understand Equivalent Circuit (as shown in Figure 2), electrochemistry reaction time (Figure 3) and current conversion equation of strips.

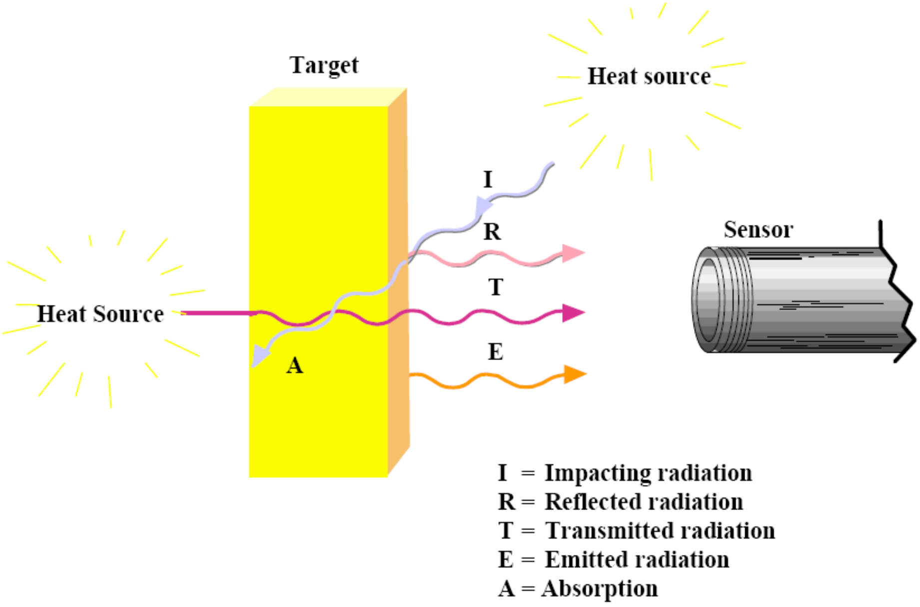


Figure 2 Interrelation of Object Radiation and Sensor Received Radiation [1]

In addition to sense the radiant emitted from the target, sensors also receive reflected radiation and the radiation can penetrate the sensors. The formula " A+R+T=1" represents the relation of impacting, reflected and transmitted radiation.

2.2.1 Emission of Black and Gray Body

Based on the formula,for solid T=0

$A + R = 1$

$\Rightarrow A = 1 - R$

$\Rightarrow E = 1 - R$

Black Body：R=0

Gray Body：R≠0，R=0.1 or 0.2…

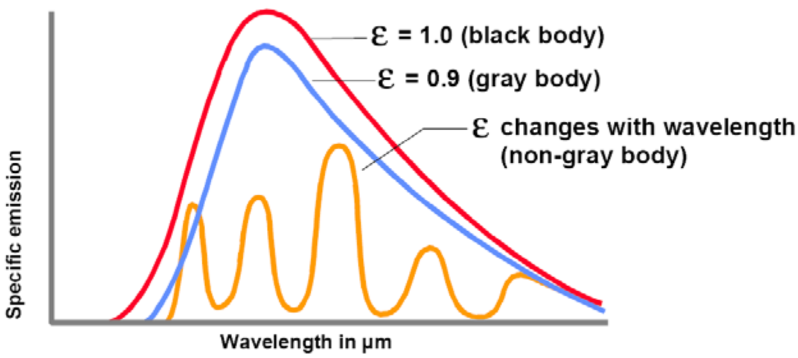


Figure 3 Relation of Emission and Wavelength of Black and Gray Body [1]

2.2.2 Measuring Metal

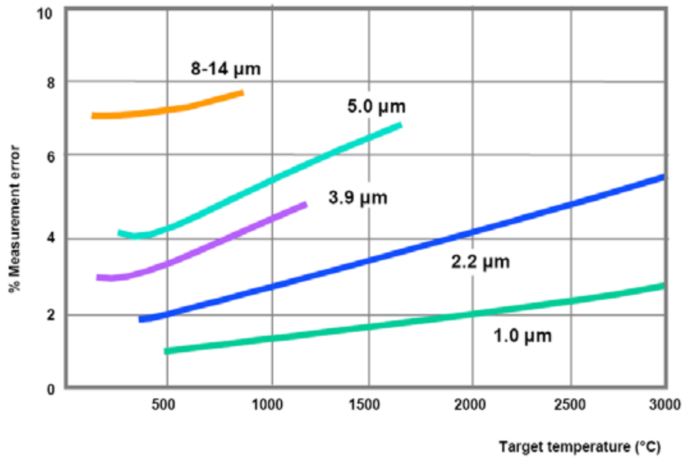


Figure 4 Measurement Error of Mental Absorption Wavelength in Different Temperatures [1]

Since metal often reflect, scattering is not easy to happen. To measure metal at particular wavelength and temperature may result in high scattering possibility. Hence, particular wavelength and temperature can increase the accuracy of metal measurement. The scattering of metal and wavelength,temperature have very close relationship. As presented in Figure 4.

2.2.3 Measuring Plastics

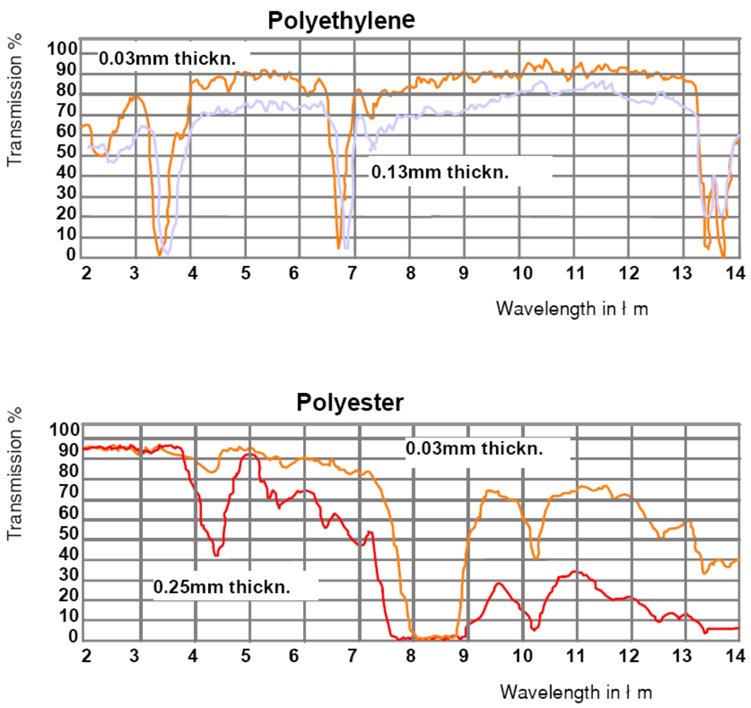


Figure 5 Relation of Different Thickness Plastic Material (Polyethylene, Polyester) Wavelength and Conduction Proportion [1]

The conduction and wavelength of certain thickness of plastic material has relative relation. In order to measure the plastic emission, it is important to know its substance and thickness, then to select the corresponding wavelength light as measuring source.

2.2.4 Measuring Glass

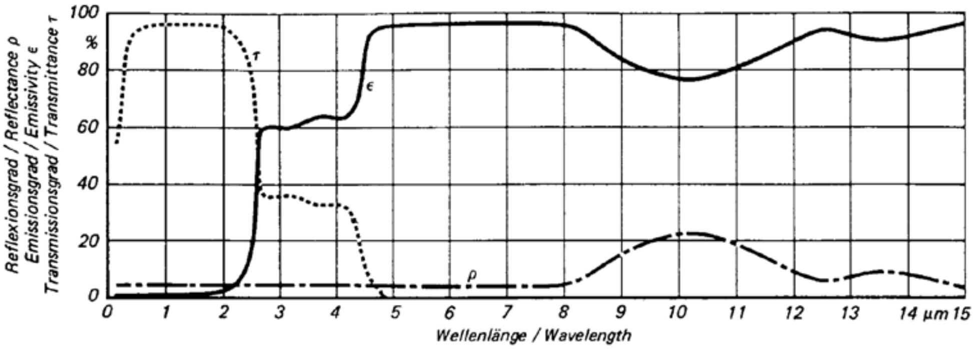


Figure 6 relation of Percentage of reflection,scattering and conduction of a Glass in different wavelength[1]

When measuring the temperature of glass with an infrared thermometer, both reflectance and transmittance are two important factors. Selecting different wavelength source will influence measuring position,for example, surface temperature(with wavelength of 5 μm)or temperature under a certain thickness(with wavelength of 1.0, 2.2, 3.9μm).The most critical factor of various glass measurements is the short response time.

2.3 Optics and Windows

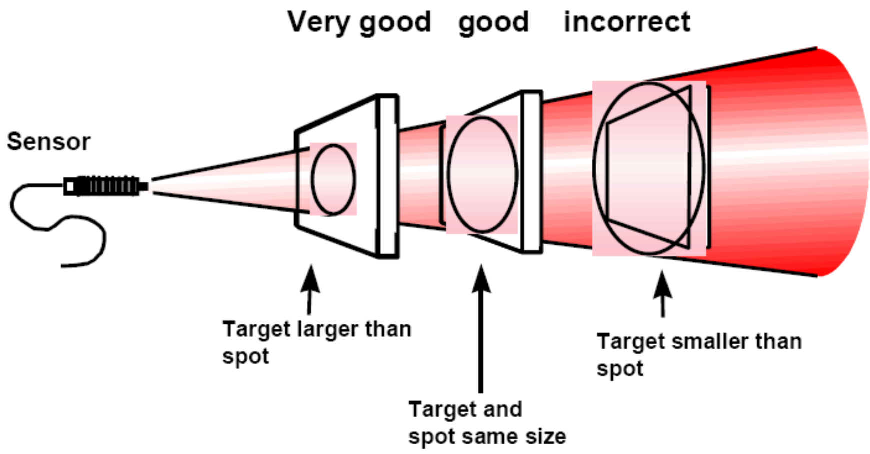


Figure 7 The target must completely contain the spot to be measured, otherwise the measured value will be incorrect [1]

Measuring the energy emitted from the target is the only key point in optical system. So the target must completely contain this spot. There are some certain relationship between energy and the measuring distance, the area of the spot. The farther the distance,the smaller the energy received by the sensor,the bigger the area of the spot.

2.4 Sensors Brief Introduction0

IR sensor

IR sensor is composed by two interface devices, Thermopile and Thermistor. Its package is as displayed in Figure 8.

Figure 8 IR Temperature Sensors [2]

Thermopile：

Thermopile outputs small voltage. The voltage value depends on object temperature and the ambience temperature where the thermopile is located, as shown in Figure 9. The recommended precision is 0.01℃. Its absolute error is within ±0.03℃ when the thermopile is used at ambient 25℃. Due to the fact that the sensor is made up of semiconductor materials, the measured result is easily influenced by temperature. A good IR sensor, the mathematical formula of the thermopile should be as below:

$$\begin{aligned} V_{out} &= K \times [(T_t + 273.13)^4 - (T_a + 273.13)^4] \\ &= K \times f(T_t, T_a) \qquad \text{............Equation (1)} \\ &= K \times [f(T_t, T_{ref}) - f(T_a, T_{ref})] \end{aligned}$$

Vout：Thermopile Voltage Output

K：Sensitivity of Thermopile

Tt：Target Temperature (℃)

Ta：Ambient Temperature (℃)

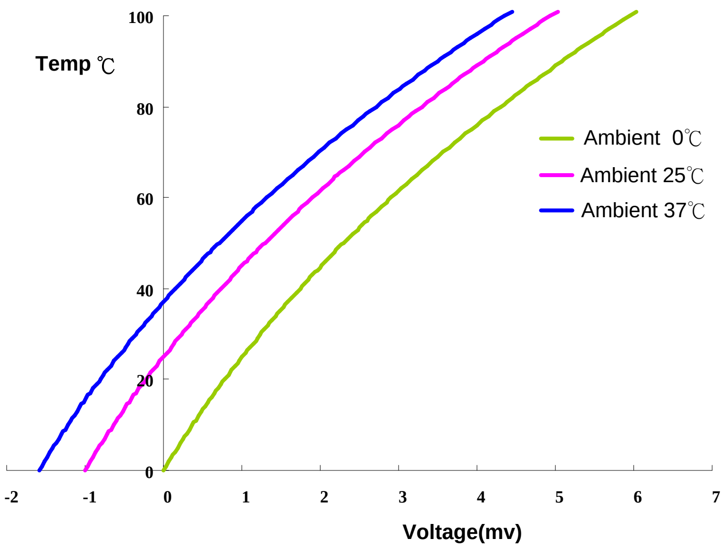


Figure 9 Thermopile Voltage and Temperature Curve

Good Thermopile equips with the following features:

- When Tt=Ta, Vout=0

- K is constant, will not change with ambience temperature.

Thermistor：

Thermistor resistance changes according to the temperature where it is located (As shown in Figure 10) and can be used to monitor the internal temperature of IR sensor. Here it is also called ambient temperature when measuring. It is suggested the measure error and repeatability should be less than 0.05°C.

Thermistor mathematical formula is given as below

$$R_{th}(T) = R_{25} \times e^{\{B\times[(\frac{1}{T+273.13})-(\frac{1}{25+273.13})]\}}$$ …………Equation (2)

$R_{th}(T)$：Thermistor resistance change value

B：Sensitivity of Thermistor

R_{25}：25℃ resistance

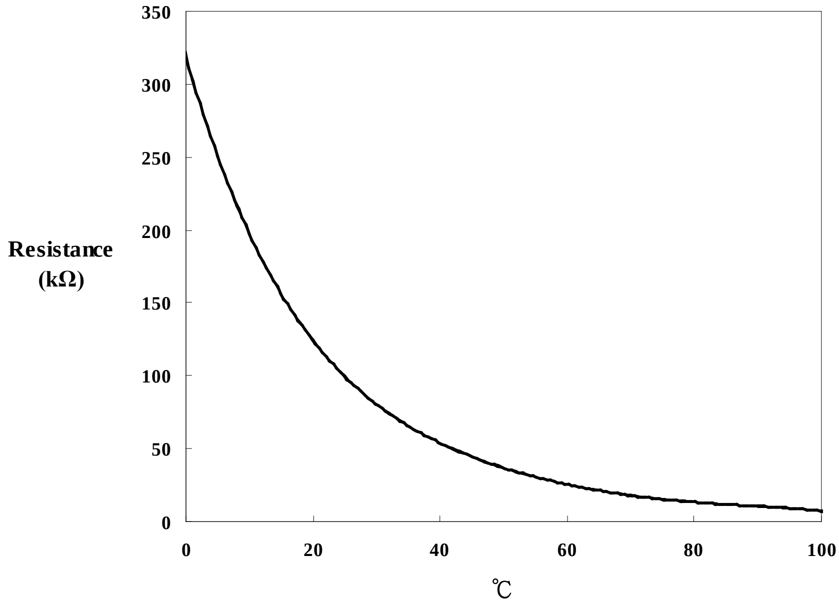


Figure 10 Thermistor Resistance and Temperature Curve

2.5 Control IC

Measure temperature signal via IR sensor and transform it to electrical signals (resistance and output small voltage). Utilize HY11P13 of HYCON Technology Corp to measure electrical signals, to operate and to display digitally, accomplished non-touchable IR temperature measurement solution in minimum components (as Figure 11 illustrated).

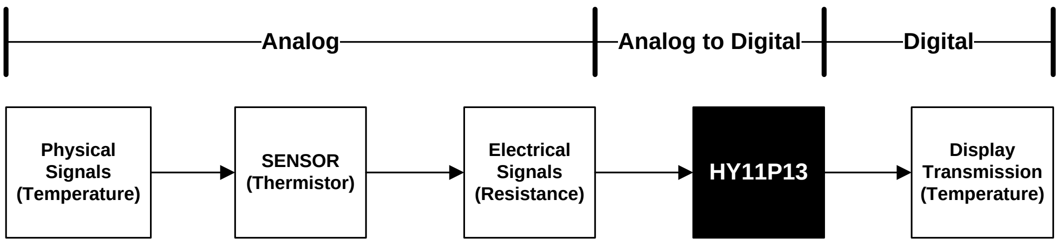


Figure 11 Analog and Digital Signal Conversion

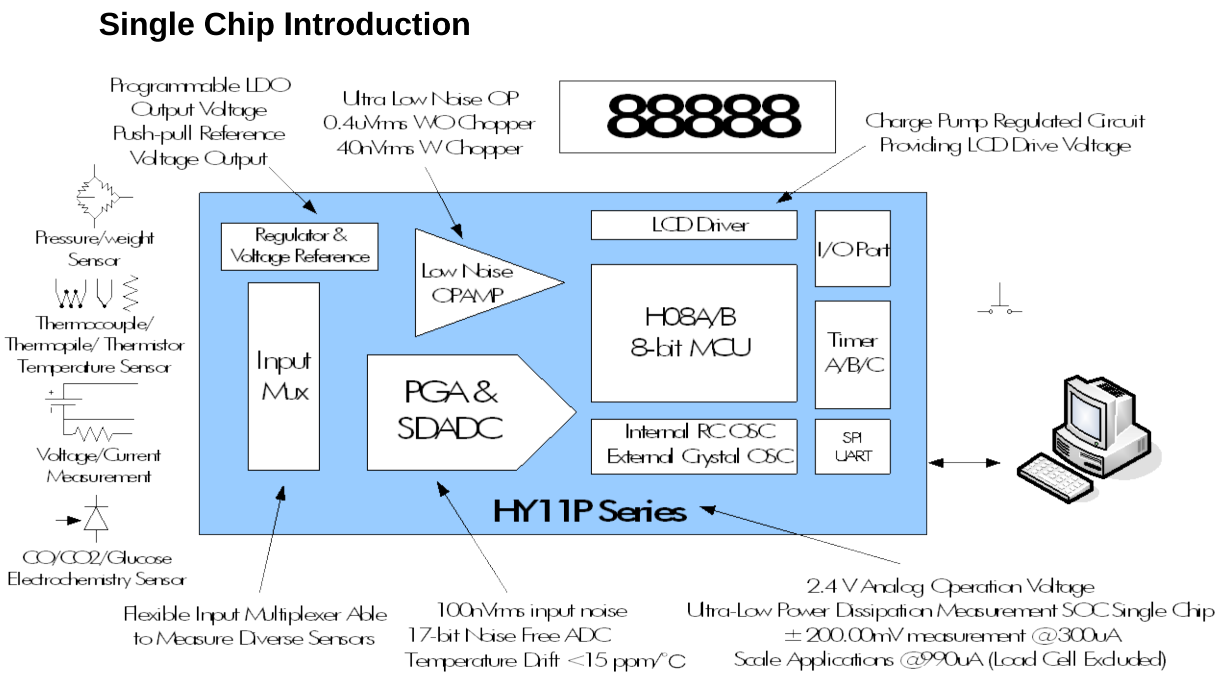


Figure 12 HY11P Series 8-bit high performance OTP Single Microcontrollers (HY11P13)[3]

- 8 bit enhanced RISC. 69 instructions in all including Hardware Multiplier Instruction and Look-up Table Instruction
- Operating voltage range: 2.0V to 3.6V, Operating temperature range: -40℃~85℃
- External Quartz Crystal Oscillator and Internal high precision RC Oscilator, 6 CPU clock rate options enable users to have the most power-saving plan
  - Run Mode 300uA@2MHz
  - Idle Mode 3uA@32KHz
  - Sleep Mode 1uA
- 4K Word OTP (One Time Programmable) Type program memory, 256 Byte data memory
- Brownout Detector and Watch dog Timer prevents CPU from crash
- 18-Bit fully differential input ΣΔADC Analog-to-Digital Converter(A/D)
  - Built-in PGA (Programmable Gain Amplifier). 1/4x, 1/2x, 1x…128x, 10 input signal gain selection
  - Built-in Input zero point adjustment can increase measurement range according to different application
  - Built-in high impedance input buffer(Not suitable for 32x or upwards input gain)
  - Built-in absolute temperature sensor
- Ultra-Low Input Noise(<1uVpp) OPA provides High Output Impedance small signal amplification and low current voltage transformation
- 1.2V low temperatures drift parameter output refer to voltage source, equips with Push-Pull drive ability to provide sensor driving voltage
- 10mA Low dropout Regulator source output which provides 4 kinds of output

voltage options.

- 4x20 LCD driver
  - Static, 1/2, 1/3, 1/4 Duty and 1/2, 1/3 Bias Software Option
  - Embedded Charge Pump Voltage Regulator Circuit with 4 LCD Bias Voltage
- 8-bit Timer A
- 16-bit Timer B Module With Capture/Compare Function
- 8-bit Timer C Module With PWM/PFD waveform Generation Function
- Serial Communication SPI Module

Introduction,Characteristic,Function….

3 Design Scheme

3.1 Hardware Illustration

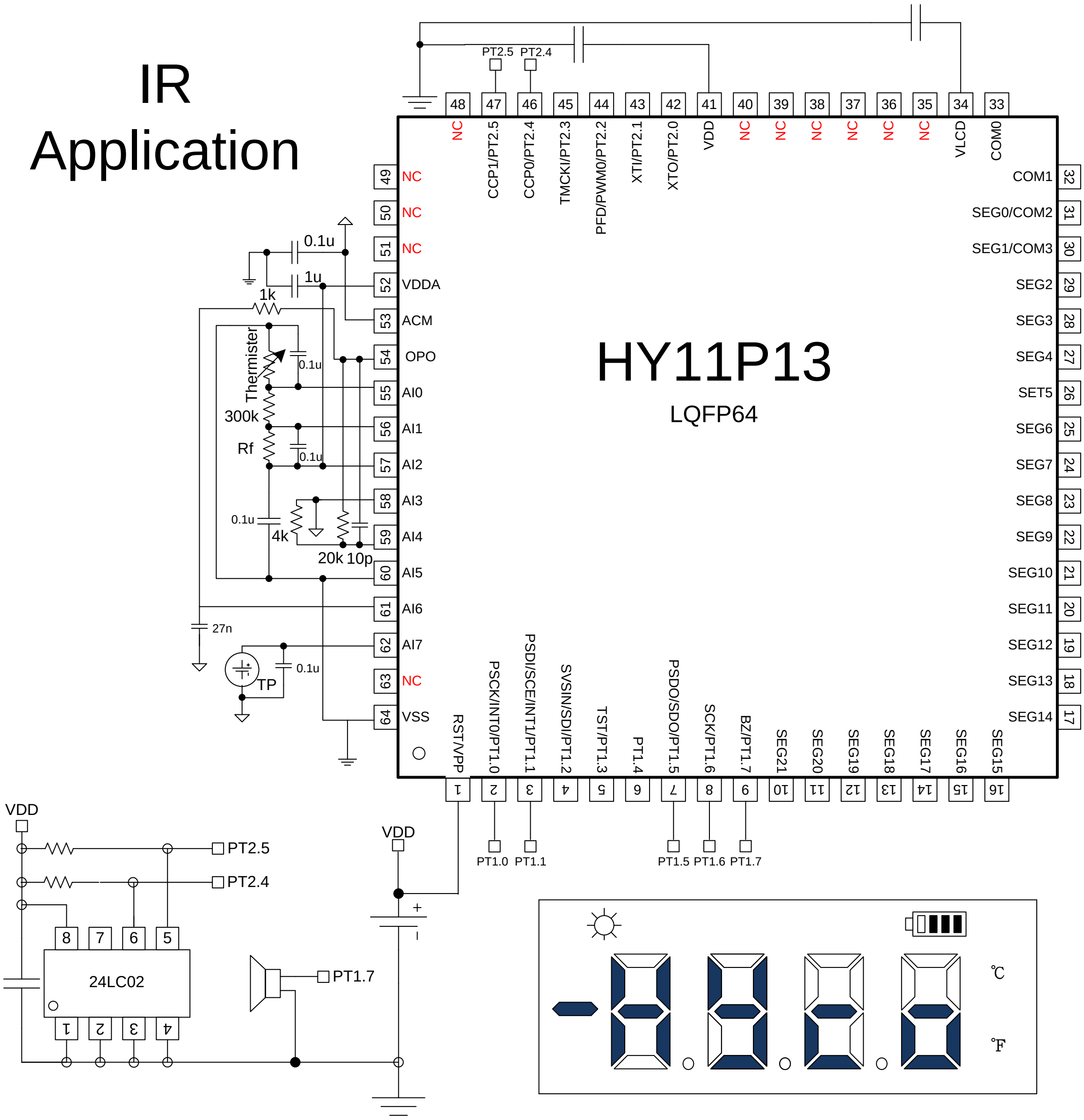


Figure 13 Application Circuit of Infrared Thermometer

Main Components Introduction

MCU: HY11P13 function to measure electrical signal, control, operate, and display.

EEPROM: 24LC02, the function is to save calibration parameters.

Sensor: M21 or Z11, the function is to convert temperature and electrical signal.

3.2 Circuit Description

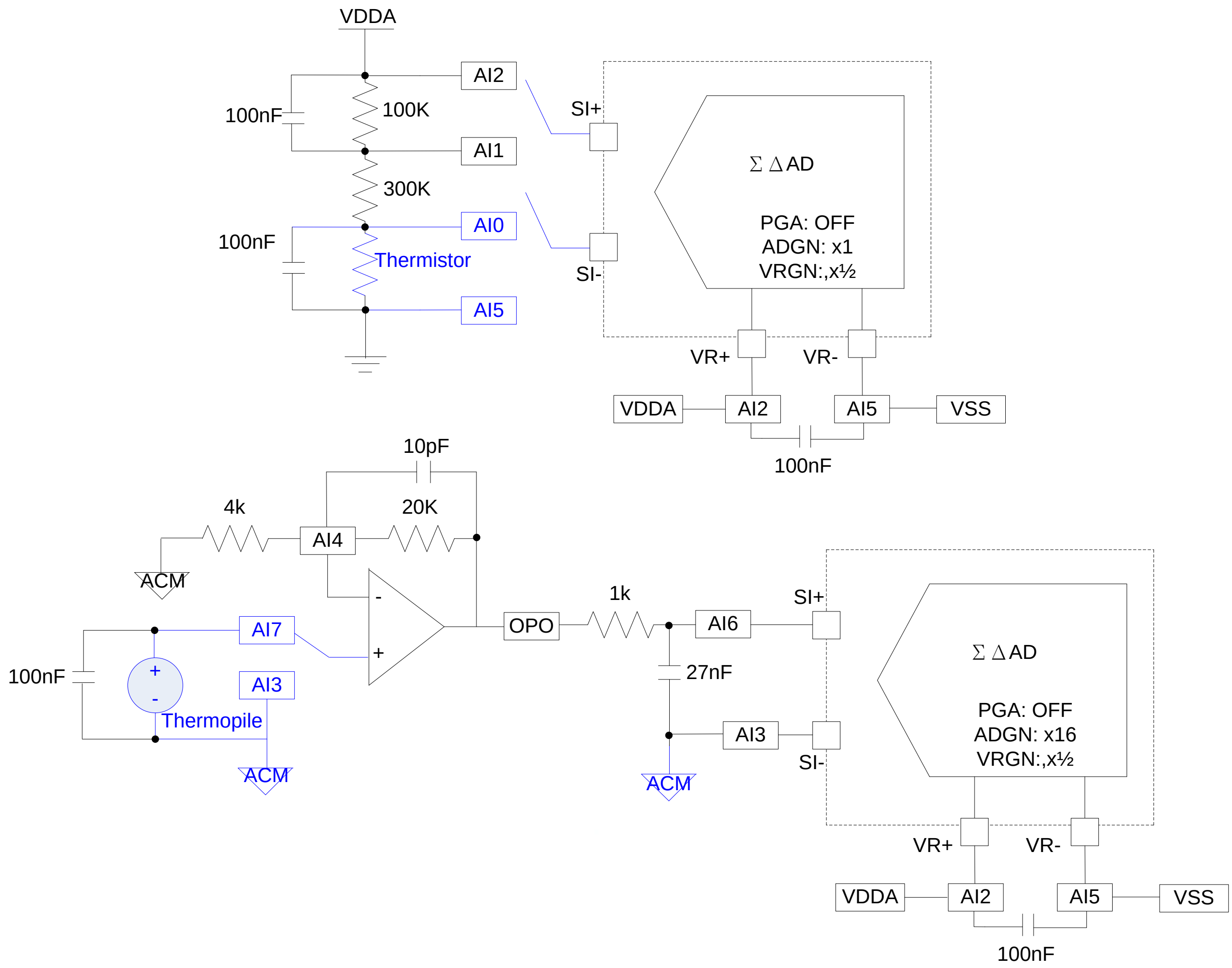


Figure 14 HY11P13 IR Temperature Measurement Network Setup

Due to the impedance match problem of thermopile, LNOP input processor OPM[1:0] must be configured as 10 or 11, without Chopper function.

Thermistor outputs different resistance in conjunction with temperature changes. Heat readiant of objects makes Thermopile to change its small voltage output. This article mainly describes how to measure electrical signal with HY11P13. The article is separated in 2 parts, resistor measurement and small voltage measurement.

37H	OPCN1	ENOP	OPM[1]	OPM[0]	OPP[1]	OPP[0]	OPN[2]	OPN[1]	OPN[0]
3CH	ADCCN1	ENADC	ENHIGN	ENCHP	PGAGN[1]	PGAGN[0]	ADGN[2]	ADGN[1]	ADGN[0]
3DH	ADCCN2			INBUF	VRBUF	VREGN	DCSET[2]	DCSET[1]	DCSET[0]
3EH	ADCCN3	OSR[2]	OSR[1]	OSR[0]					
3FH	AINET1	INH[2]	INH[1]	INH[0]	INL[2]	INL[1]	INL[0]	INIS	OPIS
40H	AINET2		VRH[1]	VRH[0]	INX[1]	INX[0]	VRL[1]	VRL[0]	

Table 1 HY11P13 Register Configuration of IR Temperature Measurement Network

Network changes for 6 times

RFZ: [ADCCN1,AINET1,AINET2]=[82H, 0CH, 48H],
Measure Rref reference resistor signal input channel offset
RF: [ADCCN1,AINET1,AINET2]=[82H, 0CH, 40H]
Measure Rref reference resistor signal (with offset)
RSZ: [ADCCN1,AINET1,AINET2]=[82H, 68H, 48H]
Measure offset of thermistor signal input channel
RS: [ADCCN1,AINET1,AINET2]=[82H, 68H, 40H]
Measure thermistor signal (with offset)
TPZ: [OPCN1,ADCCN1,AINET1,AINET2]=[C1H, 87H, 20H, 40H]
Measure thermopile offset signal (TS- signal)
TP: [OPCN1,ADCCN1,AINET1,AINET2]=[C9H, 87H, 20H, 40H]
Measure thermopile signal (TS+ signal)

Resistance Measurement：

On the procedure of measuring resistance, analog switches 4 times. After every switch, it is necessary to discard 2 data. Then save 4 data and pick up their average value as new data output. This measurement method is called alternative resistance measurement. First time measure the reference resistance, RF_count(RF-RFZ) , second time measure thermistor resistance, RS_count(RS-RSZ).

$$\frac{RF\_count}{RS\_count} = \frac{100k}{R} \quad \text{....Equation (3)}$$

R can be obtained after substitute RF_count and RS_count into equation (3). Look-up-table to convert the value as temperature.

Small Voltage Measurement：

On the procedure of measuring small voltage, analog switches 2 times. After every switch, it is necessary to throw away 2 data. Then save 4 data and pick up their average value as new data output. The purpose of TPZ analog switch is to measure the whole system ADC count after grounding. TP network is to measure signal(including system grounding signal), TP_count (TP-TPZ). VR is voltage value for the calibration. VR= corresponding voltage of objective temperature - corresponding voltage of ambient temperature

$$Gain = \frac{VR}{TP\_count} \quad \text{....Equation (4)}$$

TP_count × Gain= small output voltage, then look-up-table and transform it to temperature.

3.3 Software Illustration

3.3.1 Program Flow

This program offers test tables of two IR sensors, M21 and Z11. Users can calibrate these two sensors and conduct measurement.

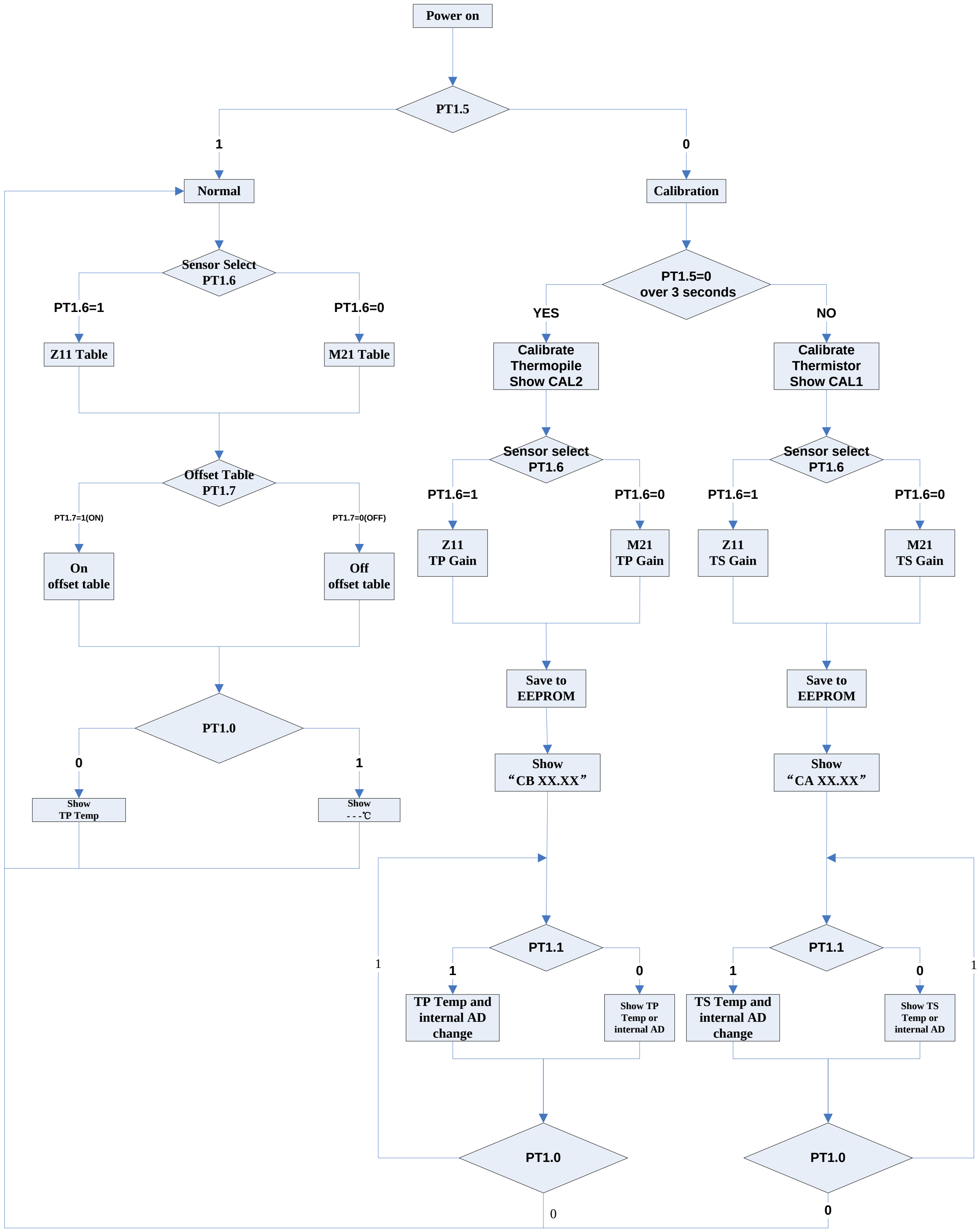


Figure 15 Program Flow

3.3.2 Calibration Flow

- Display“- - -°C” after power-on；
- Press PT1.0 to start normal measurement mode；
  - If Thermistor and Thermopile were not calibrated, continuing to display “- - -°C”；
  - If Thermistor and Thermopile were calibrated, display target temperature XX.XX°C；
- Press PT1.5 for 1-2 Sec to enter Thermistor calibration mode after power-on; when PT1.6=high, execute Z11 calibration；when PT1.6=low, execute M21 calibration；
  - Display Thermistor measurement temperature CAXX.XX°C in this mode, press PT1.1 can conduct temperature and inner code switch display；
  - Under Thermistor calibration mode, press PT1.0 to exit calibration；
- Press PT1.5 for more than 3Sec to enter Thermopile calibration mode after power-on；when PT1.6=high, execute Z11 calibration；when PT1.6=low, execute M21 calibration；
  - Display Thermopile measurement temperature CbXX.XX°C, press PT1.1 can conduct temperature and inner code switch display；
  - Under Thermopile calibration mode, press PT1.0 to exit calibration；
- PT1.7=low, turn-off temperature compensation function；when PT1.7=high, initiate temperature compensation function；
- Under normal mode, when PT1.6=low, M21 measurement is activated；when PT1.6=high, Z11 measurement is activated；
- Under normal mode, long press PT1.0 to turn off；
- Under power off mode, press PT1.0 to turn on；
- If target temperature exceeded the tabled temperature range, it will display “- - -°C”；
- Temperature compensation function is available when compensation value was written into EEPROM. EEPROM block：10H-1BH, write in verification value, 5AH to 1BH. This way, it can be determined whether the compensation value exist in the EEPROM or not.

4 Technical Specification

- Operation voltage：2.4~3.6V
- Sleep mode current：0.63uA
- Operation mode current：0.5mA
- Mode
  - Calibration mode
  - User mode
- Measure range
  - Environment Temperature:0~50℃
  - Target Temperature:0~100℃
- Calibration
  - Environment Temperature:25℃
  - Target Temperature:37℃
- Resolution: 0.01℃

5 System ESD

Due to the design characteristics of Thermopile Sensor, as below graph shows, its NTC Negative usually connects to Sensor VSS which means connected to Sensor housing. During development stage, users must consider the design of protection and anti-interference ability of the sensor’s metal probe as to avoid its stability of signal measurement. Therefore, it is important to connect Sensor NTC Negative design to system IC’s VSS. When interference occurred, VSS can help to dissipate it and achieve discharge function. Moreover, PCB Layout must be placed with extra caution.

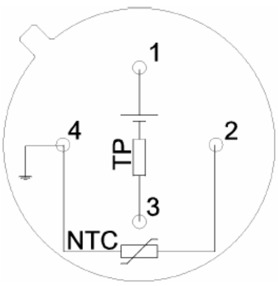


Figure 1: Electrical connections- bottom view of thermopile

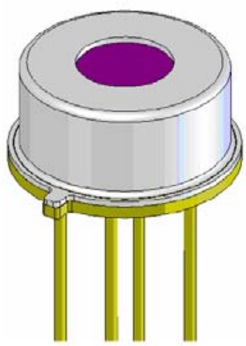


Figure 16 Bottom view of thermopile

Restrict system ESD tests were conducted directly aiming at the bare PCB sample, as shown in below graph. We not only discharged the power end but also implement ESD to the sensor housing. The anti-ESD ability of the bare PCB sample still reached high standard level even under these strict testing conditions. Test results were provided for users’ reference:

Air-gap discharge: Pass up to ±16KV;

Contact discharge: Pass up to ±8KV;

Figure 17 Bare PCB Sample test chart

This IR application has certain request for sensor peripheral circuit ground planes in PCB layout. In order to have a fast static release action when being influenced by static, it is suggested that users use VSS to shelter its signal and sensor, which aims at fast static release and preventing the accumulated impact to the system function.

Figure 18 and Figure 19 provide the top view and bottom view of PCB layout. Layout of J2 column is the actual size and place of IR Sensor, this layout should be considered by actual application, placing IR Sensor in peripheral as like ear thermometer or forehead thermometer design.

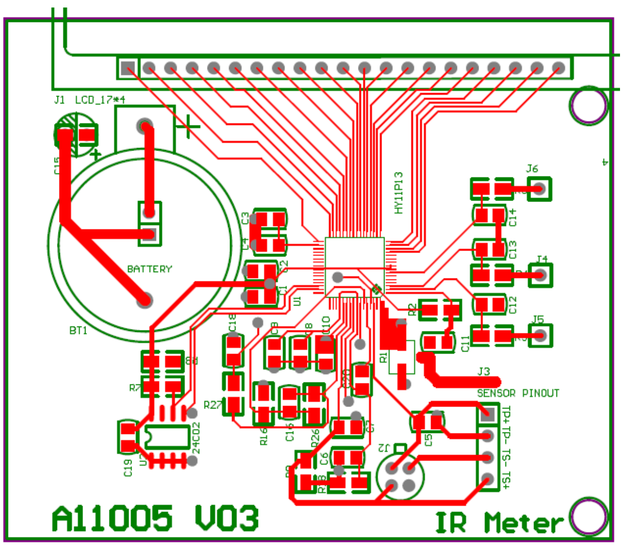


Figure 18 PCB Top View

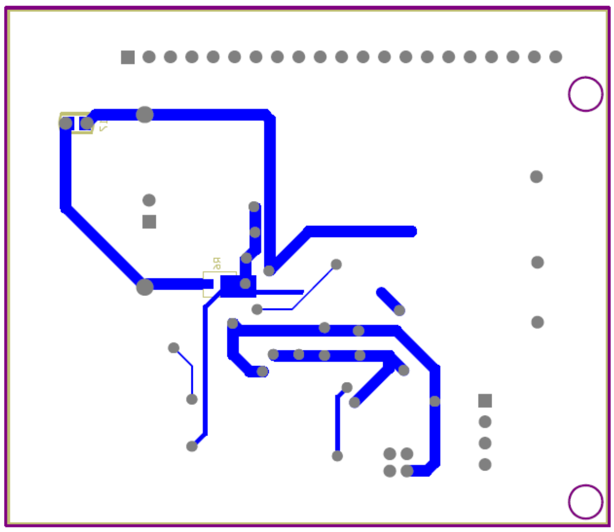


Figure 19 PCB Bottom View

Figure 20 and Figure 21 describe IR Sensor peripheral and ADC front end amplification circuit, designing VSS to completely shelter Sensor and front end OPA amplification circuit and ADC network. Ground planes entirely exist in the Sensor as VSS and were connected to the VSS pin of the IC through a short circuit resistor.

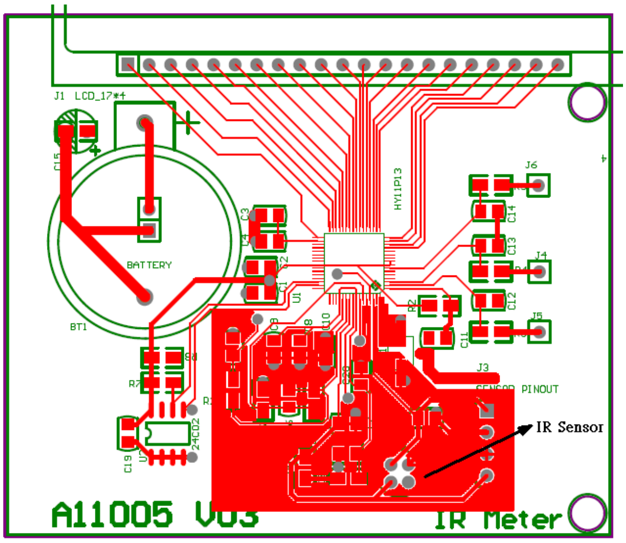


Figure 20 Sensor Ground-Top View

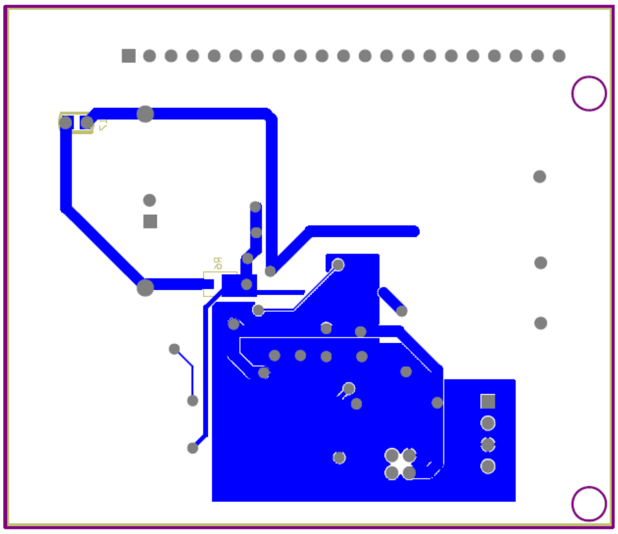


Figure 21 Sensor Ground-Bottom View

Figure 22 and Figure 23 present the graph of the IC itself and other digital pins, control pins and circuit ground, VSS. A complete VSS grounding can enhance the anti-interference ability of the system and it was connected to sensor grounding by short circuit resistor. For detailed attention of digital/analog channels of PCB layout, please refer to PCB layout suggestion application manual of HY11P series, APD-PCB001.

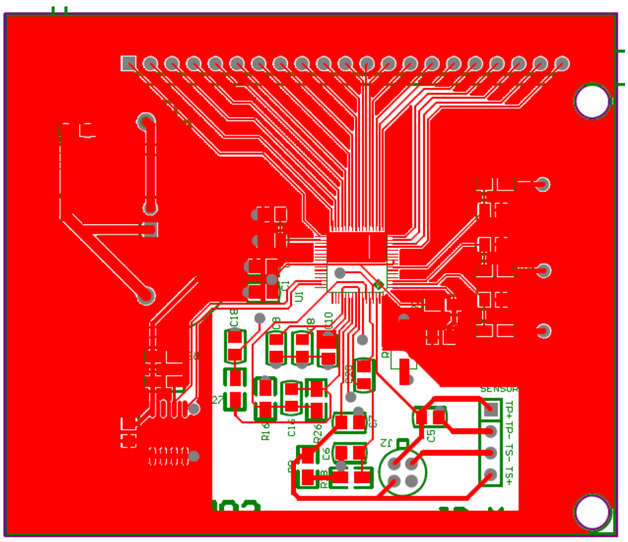


Figure 22 Chip Ground-Top View

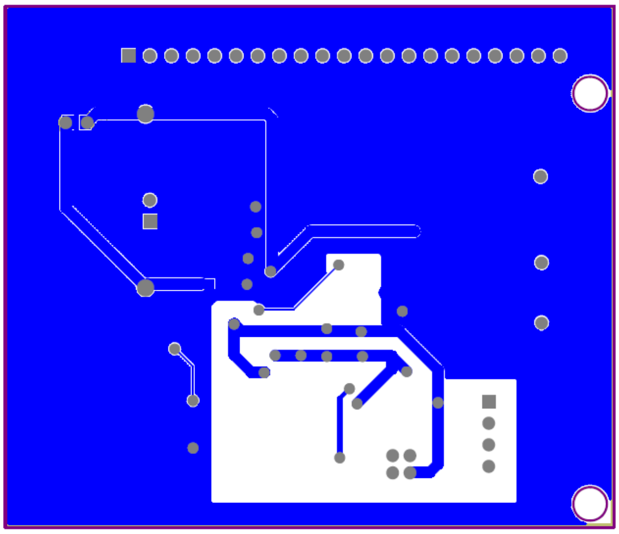


Figure 23 Chip Ground-Bottom View

6 EMC

During the development of finished goods, Electromagnetic Compatibility (EMC) test is one of the important stages that must be certificated. This article does not give illustration of EMC authentication and method, however the test results of Radiated Susceptibility (RS) of Electromagnetic Susceptibility (EMS) were provided for users' reference.

In System ESD chapter, notices of the entire layout and grounding cladding were depicted. Enhancement of EMC protection will benefit from these layout suggestions. For thermopile application, signal measurement is needed to pass through Operational Amplifier (OPA) then to Analog-to-Digital Converter of the IC due to impedance matching problem. When sampling the signal of the amplified output voltage of Thermopile, its amplification rate is in between 50~400 times. The experiment results revealed that when collocating with the built-in OPA and ADC of HYCON to carry out signal processing, OPA single-end amplification circuit that achieved the most optimum outcome was in between 10~50 times (max. 100 times). For example, if the signal amplification was designed to be100 times, it is suggested to set amplification of OPA external component as 25 times, and the amplification of built-in ADGN of ADC as 4 times to achieve 100 times amplification effect.

Below graph illustrates RS test environment. Analyzing on EN 61000-4-3 (80MHz～1GHz) of Radiated Susceptibility (RS) regulation, the object to be measured was interfered by Radio frequency(RF) signal that sent by antenna radiation, RF power. The interference frequency range is 80MHz～1GHz, ascending by 1.01 times. Test level was set as 3V/M, test directions included vertical and horizontal. Test was conducted in below conditions: distance between the object to be measured and the antenna were 3 meters in non-electromagnetic wave reflection room, 80% Amplitude Modulation (AM) and 1KHz carrier. The test results indicated that maximum temperature change was within ±0.3℃.

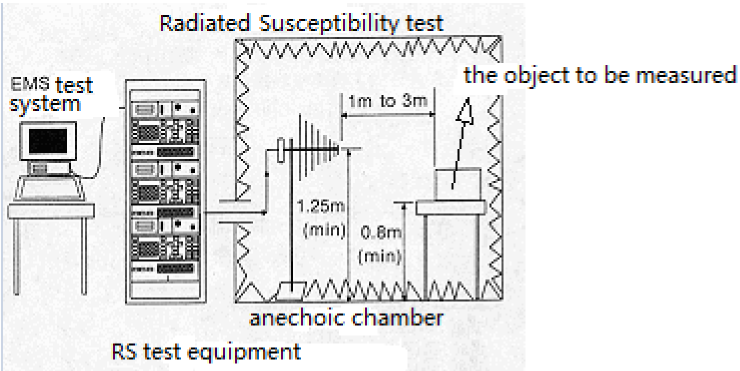
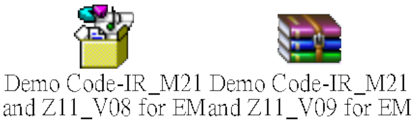


Figure 24 RS Test Environment

7 Demo Code and Related File

Main program: Demo Code-IR_M21 and Z11_V09 for EMI (Gain16).rar

Assembly file: IR.asm



8 References

[1] “Principles of Noncontact Temperature Measurement” http://www.raytek.com

[2] ISHIZUKA ELECTRONICS CORPORATION http://www.semitec.co.jp/

[3] HYCON Technology Corporation http://www.hycontek.com/

9 Revision Record

Major differences are stated thereinafter,with punctuation and font excluded.

Version	Page	Revision Summary
V01	All	First Edition
V02	All	Add Demo Code
V03	All	Update test circuit and Demo code collocating with Sensor
V04	16-18	Add System ESD test content and prevention description
	19	Add EMC test content and prevention description
V05	19	Demo Code update to V09；revise the problem that if ADC Output is negative number which may cause error of measurement.