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ADC error solution in WiFi ESP8266

The analog digital convertor’s documentation of the ESP8266 circuit is poor and unprecisely. We’ve observed these problems doing our first experiments with the ESP-12 module.

The documentation is sugesting the analog reference Aref is **exactly 1,0V**.
There must be 1024 analog to digital conversion steps when aplying 1,0V at the ADC input.

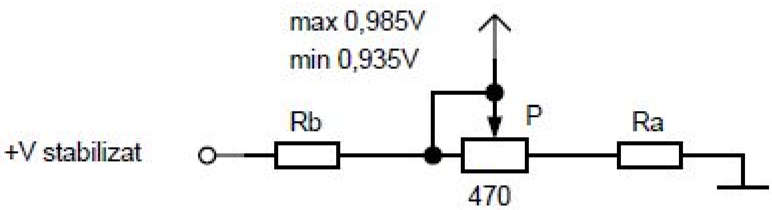
Our experiments show something else !

In reality, Aref ≠ 1,0V, varying from module to module. The convertion steps number are not equal with the design requirements. These errors cannot be accepted.

Note 1: Until **2.3.0** ESP8266 library version, Aref > 1V, the centered value = 1,07V.
The **2.4.0 - rc2** version makes Aref < 1V, the centered value = 0,97V, 100mV less.
The new centered value is near close to the ideal 1,0V, but **the error is still existing**.

This tutorial helps the users having the same problem.

Our solution is based on the Aref experimental determination value for each ESP-12 module.

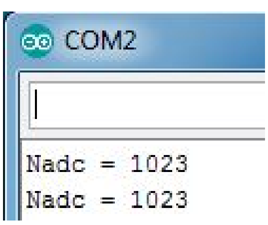


Starting from the +V stabilised voltage value you have, dimension the divisor so that when turning the P potentiometer, the slider voltage value to be included between 0,935~0,985V.

Upload the check_analog_ref.ino programm and solder the P slider to the ADC / ESP-12 input.

Rotate the potentiometer until the Nadc steps number printed on the serial Arduino monitor fit 1023~1024 limit. The P slider’s measured voltage is the Aref analog reference value.
Write this value on the ESP-12 module. You’ll need it!

```
void loop() {
  int Nadc = analogRead(A0);
  Serial.print("Nadc = ");
  Serial.println(Nadc);
  delay(1000);
}
```



The ambiental temperature measured with the KTY81-210 transducer

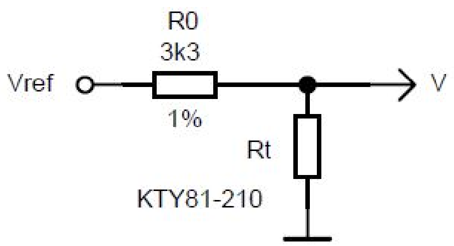
We measure the ambiental temperature in the -40~+40 °C range, precisely, cheap and efficient:

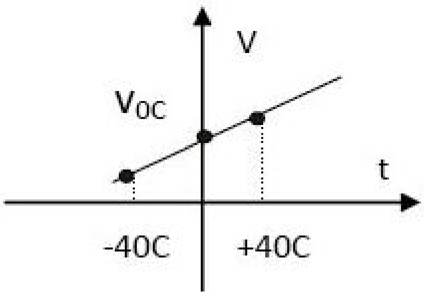
- The KTY81-210 transducer is a thermistor. The transfer function liniarity is done by the help of the serial R0 resistor

- The transducer may be placed at max 50m distance with a twin braid 2x0,75mm² wire.

The KTY81-210 transducer equations

The R0 = 3300Ω value is providing a very good output voltage V linearity depending on **t** temperature and not depending on Vref voltage.

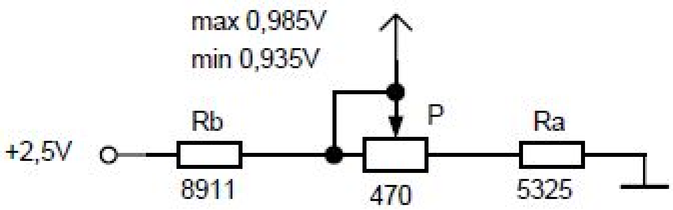




$$V = Vref \frac{Rt}{Rt + R0} \quad (1)$$

choose Vref = 2,5V.

The designed divisor to measure the ESP-12 analog reference Aref value is:



The Ra and Rb values result from calculations when P = 470 Ω, but the P tolerance is 20%.
The exactely Ra and Rb values are calculated using the P measured value:

- Ra = 11,33 x P
- Rb = 18,96 x P

The Ra and Rb values are done by serial pieces to fit the values.

The KTY81-210 catalog paper show the Rt values at various temperatures:

- 1630Ω at 0°C
- 1135Ω at -40°C
- 2245Ω at +40°C
- 2417Ω at +50°C
-

The transducer's output voltage V may be written as a strait line depending on the temperature t:

$$V = \alpha * t + V_{0C} \quad (2)$$

The Voc and α numerical values are resulting from the equation (1).

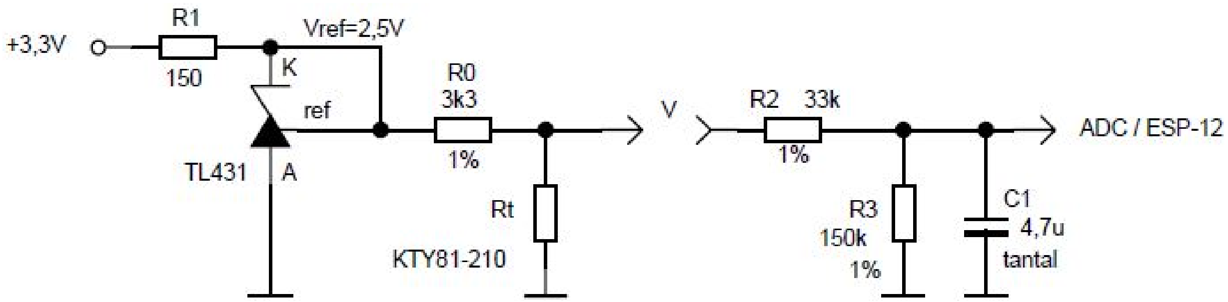
$$V_{0C} = 2{,}5 * \frac{1630}{1630 + 3300} = 0{,}826572V$$

$$V_{-40C} = 2{,}5 * \frac{1135}{1135 + 3300} = 0{,}639797V$$

$$V_{+40C} = 2{,}5 * \frac{2245}{2245 + 3300} = 1{,}0121731V$$

$$\alpha = \frac{V_{+40C} - V_{-40C}}{40C - (-40C)} = \frac{1{,}0121731 - 0{,}638797}{80} = 4{,}6547 * 10^{-3} V/'C$$

The electronic design is:



The R2, R3 divisor drops the V transducer's delivered value to fit the ADC / ESP-12 input range.

The ESP-12 ADC input is converting the divisor's voltage into Nadc steps number depending on the experimental obtained Aref voltage value.

$$V * \frac{R3}{R2 + R3} = Nadc * \frac{Aref}{1024} \qquad (3)$$

replace Ra, Rb values and send to the right

$$V = Nadc * \frac{Aref}{1024} * \frac{183}{150} \qquad (4)$$

Eliminate the V variable in the equations (4) and (2):

$$\alpha * t + V_{0C} = Nadc * \frac{Aref}{1024} * \frac{183}{150}$$

Extract the **t** temperature and replace α and Voc with their above calculated values:

$$t = Nadc * \frac{Aref}{1024} * \frac{183}{150} * \frac{1000}{4{,}6547} - \frac{826{,}572}{4{,}6547} \qquad (5)$$

Amplify the ecuation with 10.000 and finaly divide it only with 1.000:

$$t * 10 = \frac{Nadc * \frac{(Aref * 10000)}{1024} * \frac{183}{150} * \frac{1000}{4{,}6547} - \frac{8265720}{4{,}6547}}{1000}$$

do some partial calculations:

$$t*10 = \frac{Nadc*Aref*1830000}{714961{,}92} - 1776 \qquad (6)$$

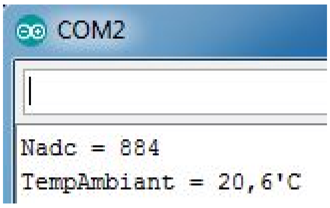
Our ESP-12 exemplar has **Aref = 0,9716V**, experimentaly obtained.

Replace Aref value in (6), do the Aref x 1830000 multiplication and round the integer values:

$$t*10 = \frac{Nadc*1777845}{714962} - 1776 \qquad (7)$$

Write the equation (7) in the adc_kty81_210.ino programm. The programm is printing the signed integer part, the decimal comma and the first decimal of the measured temperature:

```
Serial.print("TempAmbiant = ");
Serial.print(TempAmbiant/10);          //temperatura in valoare intreaga si semn
Serial.print(",");                     //virgula zecimala
Serial.print(abs(TempAmbiant)%10);     //valoarea zecimala cu ajutorul functiei modulo 10
Serial.println("'C");
```

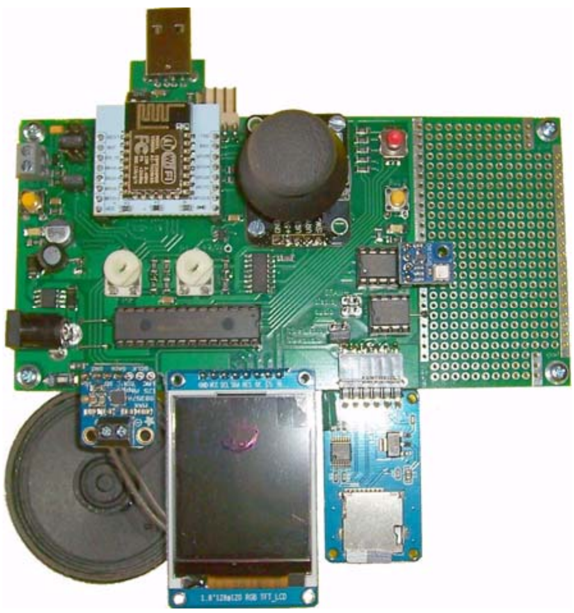


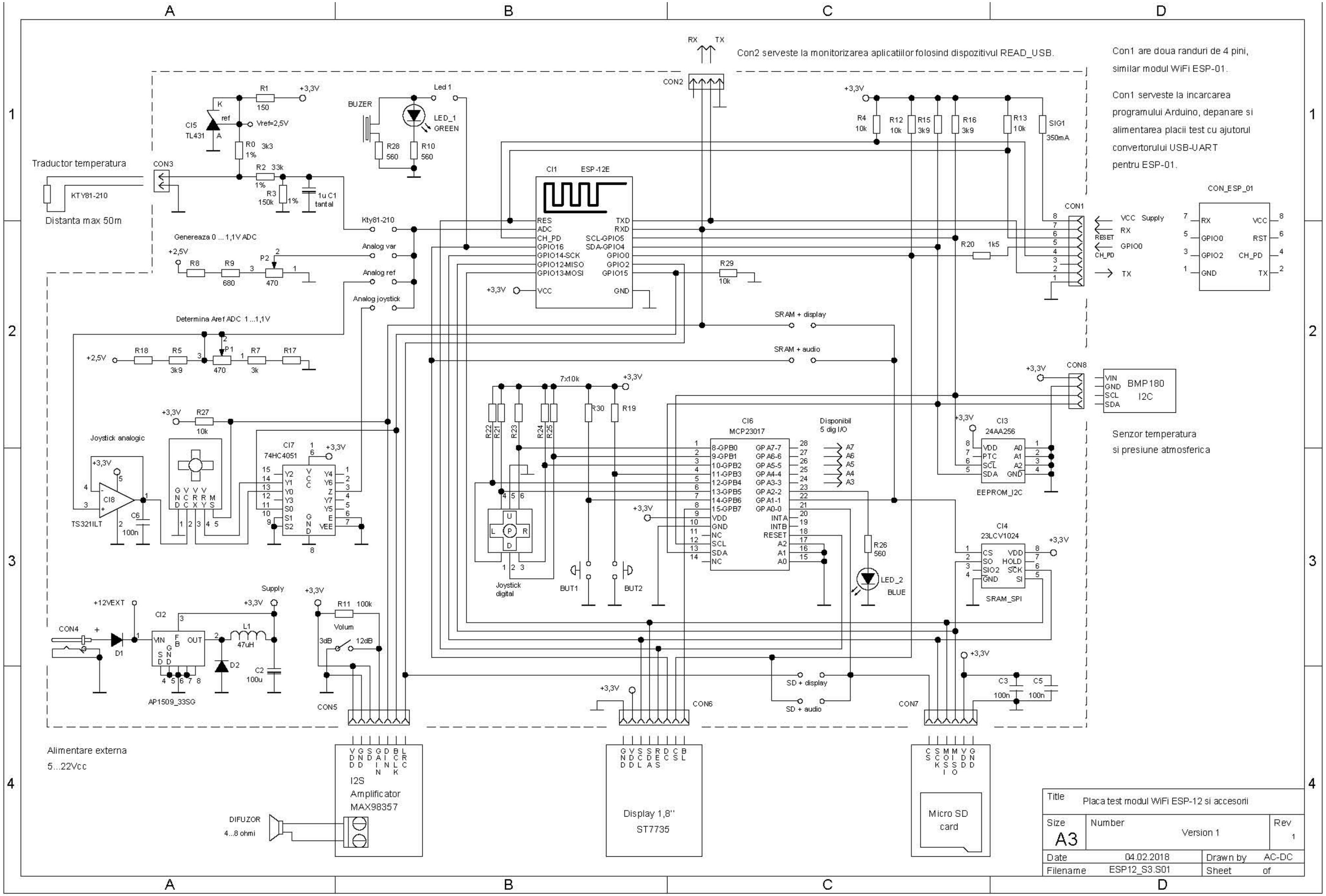
Note 2: Our experiments have been done using five ESP-12 samples. The experimental Aref obtained voltages were 0,9756V, 0,9672V, 0,9853V, 0,9715V, 0,9859V si 0,9791V.
A 3 ½ digital voltmeter is required.

Note 3: We've avoided the float arithmetics operations. The measured resolution is ~ 0,3 °C.

Run also the adc_kty81_210_isr.ino and web_kty81_210.ino examples.

The WiFi ESP-12 test board and accesories




Con2 serveste la monitorizarea aplicatiilor folosind dispozitivul READ_USB.
Con1 are doua randuri de 4 pini, similar modul WiFi ESP-01.
Con1 serveste la incarcarea programului Arduino, depanare si alimentarea placii test cu ajutorul convertorului USB-UART pentru ESP-01.
Traductor temperatura
KTY81-210
Distanta max 50m
Genereaza 0 ... 1,1V ADC
Determina Aref ADC 1...1,1V
Joystick analogic
Joystick digital
CI1 ESP-12E
CI2 AP1509_33SG
CI3 24AA256 EEPROM_I2C
CI4 23LCV1024 SRAM_SPI
CI5 TL431
CI6 MCP23017
CI7 74HC4051
CI8 TS321ILT
BMP180 I2C
Senzor temperatura si presiune atmosferica
CON_ESP_01
Disponibil 5 dig I/O
SRAM + display
SRAM + audio
SD + display
SD + audio
Alimentare externa 5...22Vcc
DIFUZOR 4...8 ohmi
I2S Amplificator MAX98357
Display 1,8'' ST7735
Micro SD card
Title Placa test modul WiFi ESP-12 si accesorii
Size A3
Number Version 1
Rev 1
Date 04.02.2018
Drawn by AC-DC
Filename ESP12_S3.S01
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