NTC Temperature Compensation of a Common Emitter Voltage Amplifier

INTRODUCTION

NTC thermistors are still widely used for temperature compensation of electronic circuits.

In the “hardware compensation method” the negative change of electrical resistance is used to correct the temperature coefficient of several electronic devices (fixed resistors, diodes, transistors, amplifiers, IC´s, quartz oscillators, etc.).

In the example described hereunder, we present the guidelines needed to design a thermistor in a simple class A common emitter amplifier.
However, the principles described here are applicable to more complex amplifiers like class B Push Pull amplifiers.

THE COMMON EMITTER CIRCUIT

Let us build a circuit operating as a voltage amplifier with a voltage gain of 50, a quiescent current of 1 mA, and a power supply voltage of Vcc of + 20 V, for signals from 20 Hz to 20 kHz.
We expect this amplifier stage to be stabilized in temperature ranging from 25 °C to 55 °C. The highest temperature can be easily reached by a transistor in operation.

In order to do this, consider the common emitter amplifier in Figure 1.

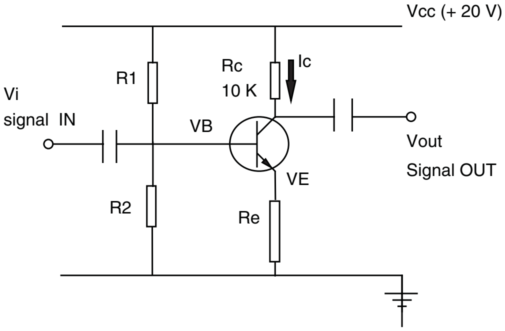

Figure 1.

The different values for the fixed resistors (R_C, R_E, R_1, and R_2) are designed as follows:

1) The collector resistor Rc is chosen in order to have a maximum output voltage without clipping – that is an output voltage (V_{out}) at 0.5 x V_{cc} = 10 V.
The quiescent collector current Ic has to be 1 mA,
Rc = 10 V/1 mA = 10 kΩ.

2) RE is chosen so that the required voltage gain is reached - that is:

$$\text{gain} = V_{out}/V_{in} = -50 = -Rc/(RE + rE)$$

Where rE is the small signal impedance looking into the emitter = V_T/I_c = 25 Ω. (V_T = k T/q, k is the Boltzmann constant, T is the absolute temperature, and q is the charge of an electron).

Thus, RE = 10000/50 - 25 = 175 Ω. As a consequence, the emitter voltage VE is 175 Ω x 10 - 3 A = 0.175 V.

3) R_1 and R_2 are chosen to polarize the base at a voltage equal to VE (0.175 V) plus the voltage drop on the base emitter junction (0.6 V) – that is 0.775 V.

Thus:

$V_B = R_2/(R_1 + R_2)\ V_{cc} = 0.775$ V
$R_1/R_2 = 19.225 / 0.775 = 25$ approx.

For example: R_1 = 250 kΩ and R_2 = 10 kΩ

TEMPERATURE COMPENSATION OF THE AMPLIFIER

During operation, power is dissipated into the transistor resulting in an increase of its temperature. Accordingly, for an increase of 1 °C, the base emitter voltage will drop 2.1 mV.
As the base voltage is kept constant with the polarization network R1 and R2, the emitter voltage will rise 2.1 mV per increase of 1 °C.
We will assume here the voltage drop is changing linearly with temperature, by 2.1 mV/°C.

For example, at 55 °C, there is a temperature increase of 30 °C, VE will approximately rise to 0.175 + 30 x 0.0021 V = 0.23 V.
In these conditions, Ic will rise from 1 mA to 0.23/175 = 1.36 mA, which represents an increase of + 36 %.
This could eventually lead to thermal runaway of the bipolar transistor.

In order to avoid this, a simple method is to let the base voltage decrease as the temperature increases, by replacing the polarization resistance R_2 by a compensation network with one fixed resistor R_2’ with a thermistor R_θ in parallel (as shown in Figure 2).

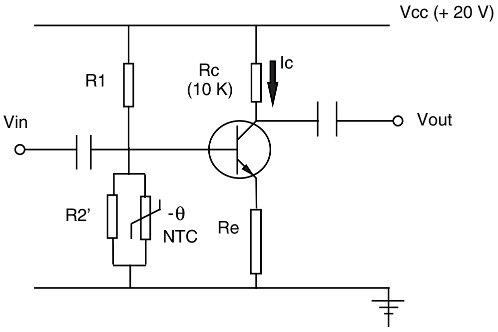

Figure 2.

COMPUTATION OF NTC PARAMETERS

When the temperature increases from 25 °C to 55 °C, the base voltage has to decrease from 0.775 V to 0.775 - (55 - 25) 0.0021 V = 0.712 V.

Thus at 25 °C:

$R_1/(R_2' R_\theta/(R_2' + R_\theta)) = (20 - 0.775)/0.775 = 25$

At 55 °C:

$R_1/(R_2' R_\theta/(R_2' + R_\theta)) = (20 - 0.712)/0.712 = 27$

Taking into account the electrical resistance-temperature for a thermistor:

$R_\theta(T) = R_\theta(25\ °C) \exp (B25/85\ (1/T - 1/298.15)$

Or more accurately

$R_\theta(T) = R_\theta(25\ °C) \exp (A + B/T + C/T^2 + D/T^3)$
(A, B, C, D being the Steinhart & Hart coefficients)

After some computations, taking as reference values:

R_1 = 250 K R_2' = 10300 Ω
<u>NTC characteristics of 2381 615 5x 334:</u>
R_θ (25 °C) = 330 kΩ with B25/85 = 3930 K
and R (55 °C) = 100058 Ω

We obtain the compensation effect represented in Figure 3.

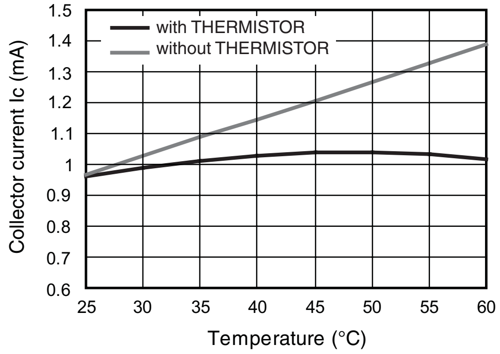

Figure 3. Temperature Compensation of a Common Emitter Voltage Amplifier

POSITION OF THE THERMISTOR IN THE CIRCUIT

Of course, if we want the best compensation possible, the thermistor should be the same temperature as the transistor and in good contact with the heat sink.
Thermoconductive paste could be helpful to reach this goal.
A simple general solution for any compensation scheme would be to solder the compensating SMD NTC on the opposite side of the PCB onto which the heat sink with the transistor are screwed on (as shown in Figure 4).
The thermal contact between the SMD component and the heat sink can be realized by drilling a hole into the board and filling the hole with thermoconductive paste.

In practice, the correlation between the temperature of the thermistor and the temperature of the transistor should always be worked out.

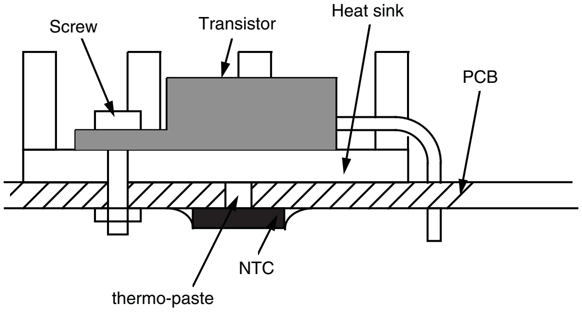

Figure 4.