Industrial Instrumentation

MINI PROJECT

Title:

Temperature-to-Period Thermistor Circuit Design

Sudharshan Suresh

Senthil Hariharan A

Surya N

Shyam Sundar Sekar

Aim:

To convert variation in temperature reading from an NTC-type thermistor to variation in time period of a square-pulsed output signal.

The existing thermistor setup provides only non-linear output, with resistance decreasing with increasing temperature.

This output can be observed via oscilloscope or microcontroller ADC setup.

Components Required:

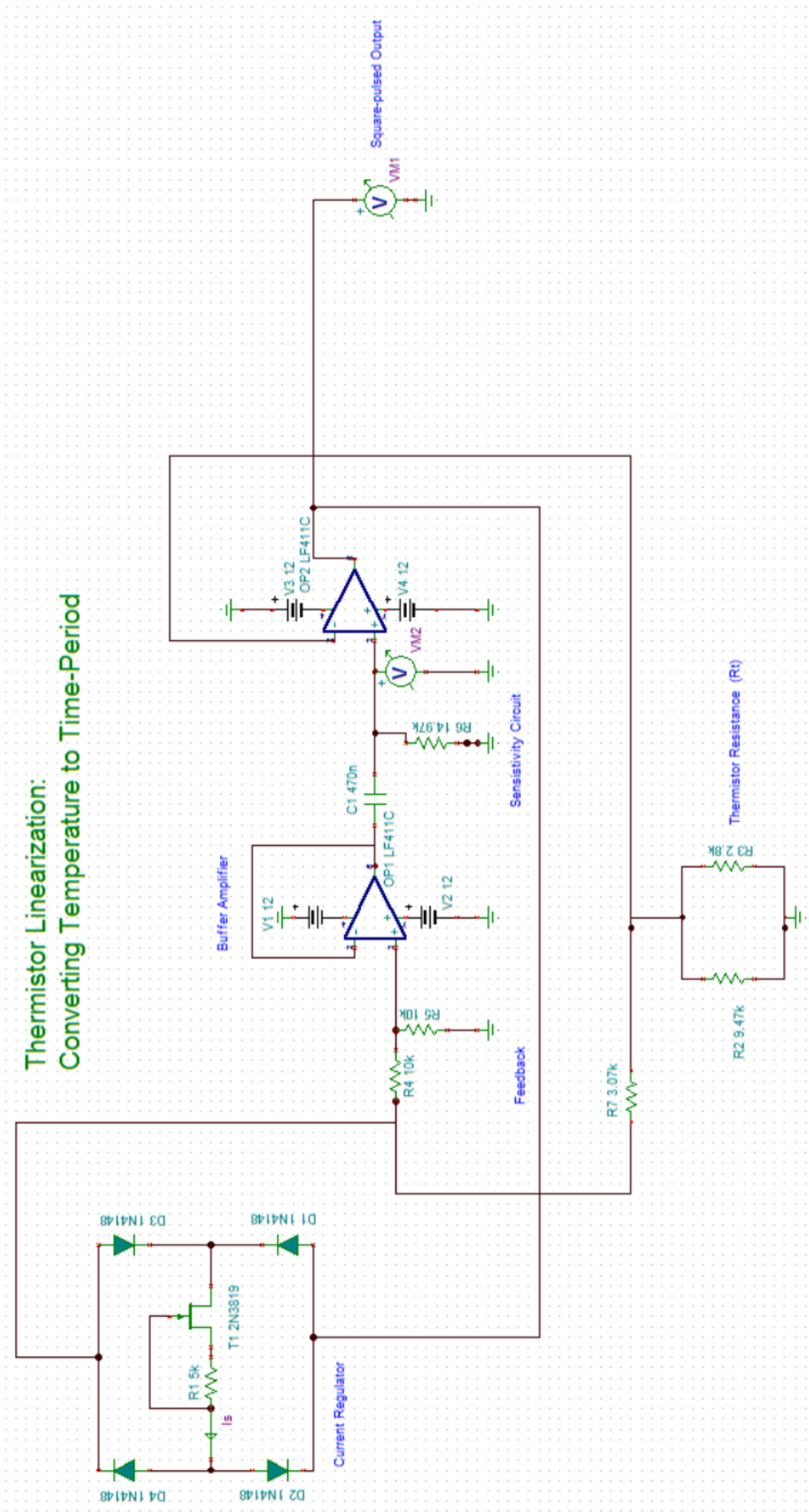
Specific Requirements:

I.	Thermistor NTC-type (10K)	-----	1
II.	LF411 Op-Amp	-----	2
III.	Potentiometers	-----	2
IV.	Assorted Resistor Box	-----	1
V.	Diode 1N148	-----	4
VI.	2N3819 N-Channel JFET	-----	1

General Requirements:

VII. Regulated Power Supply (± 12V)
VIII. Oscilloscope
IX. Breadboard
X. Connecting Wires
XI. Multimeter

Circuit Schematic:



Working Principle:

Thermistors are widely used today owing to many properties they hold including high sensitivity, low cost and small time constant including others. Considerable efforts have been made in linearizing the response of a thermistor, one such being the use of the **Bosson's law:**

The law states that the Resistance of a thermistor can be related to the temperature of operation of the thermistor as:

$$\mathbf{R_T = AB^{-\theta}}$$

Where $\mathbf{R_t}$ is the Resistance of the thermistor and $\boldsymbol{\theta}$ is the temperature of operation. This relation holds good for an actual thermistor for a narrow range of temperature. However, upon adding a suitable parallel resistance across the thermistor, the effective resistance closely resembles the temperature relation of the Bosson's law.

Exploring Bosson's Law

Bosson's Law is initially represented as:

$$\boldsymbol{R = A + \frac{B}{T + \theta}}$$

In the equation, quantities A, B, and ϑ represent certain thermistor constants, and temperature, T, is in kelvins. By taking the exponent of both sides, we get

$$\boldsymbol{R \ = e^{A} \times e^{[\frac{B}{T+\theta}]}}$$

If we replace the constant $\boldsymbol{e^A}$ *with* $\boldsymbol{A}$*, we can restate Bosson's Equation as*

$$\boldsymbol{R \ = A \times e^{[\frac{B}{T+\theta}]}}.$$

With suitable assumptions, the literature derives the approximation $\boldsymbol{R = AB^{-\theta}}$ *from the Bosson Form.*

The Network under study uses operational amplifiers for the generation of a desired output in the form of square waves. These waves have their time period, and thereby, the frequency linearly varying with the resistance connected in position AB. When a thermistor along with a parallel resistance is used, the thermistor has a linear variation in temperature in a known range which can be calibrated to find the operation temperature.

The circuit has a constant current source made from a network of diodes. The output current is varied by varying the parameters of the JFET Q and resistance R_s. This source is given as the input for the Op-amp IC1, which causes excitation in the RC circuit that follows. Exponential decay of the voltage across the resistor R1 is seen when R2 is greater than R_{AB}. At the instant when the decaying voltage across R_1 falls below the voltage across thermistor R_t, the output of the comparator changes its state. The oscillations in the circuit gives rise to a square wave form, whose period of oscillation is given as,

$$\boldsymbol{T = 2R_1C_1 \ln\left(\frac{R_2}{R_{AB}}\right)}$$

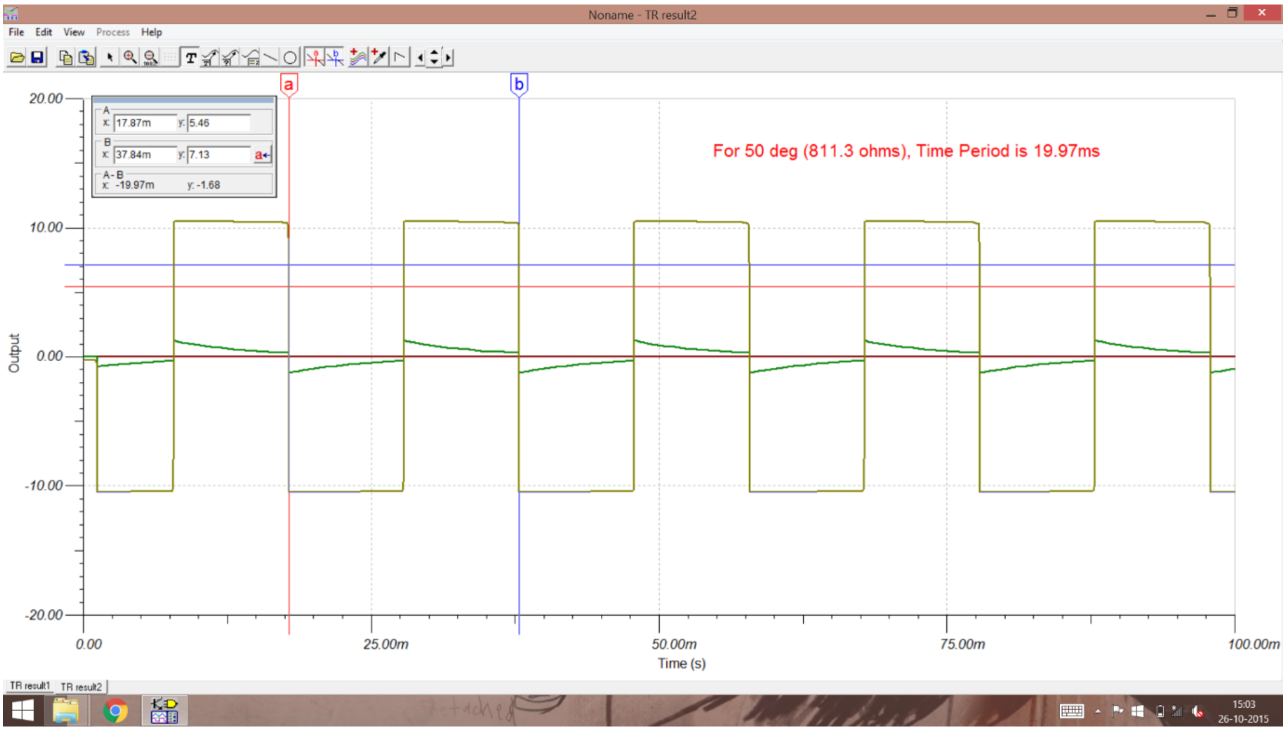
Using the Bosson's law we get,

$$\boldsymbol{T = 2R_1C_1 \ln\left(\frac{R_2}{A}\right) + \theta lnB}$$

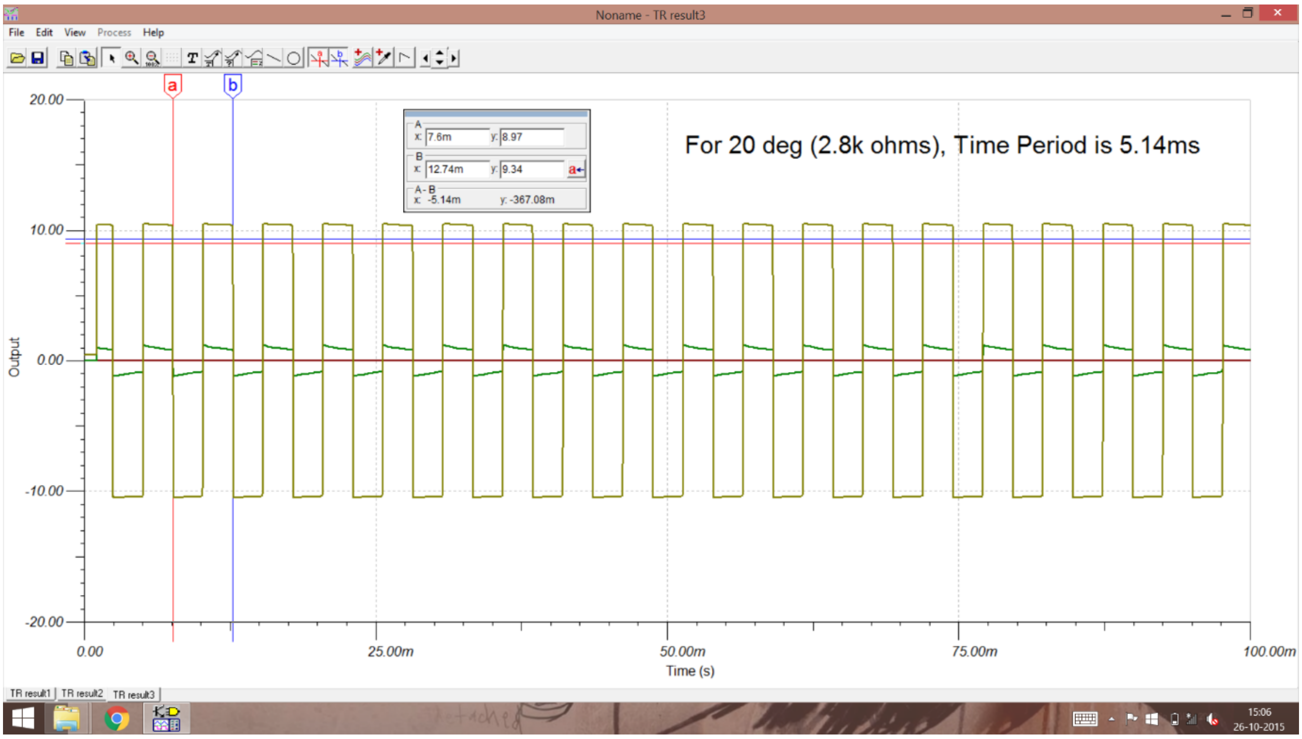
We find that the time period is linearly dependent on the temperature of operation. The Time period of the wave is obtained with the help of an oscilloscope. The temperature is then calculated with the help of a lookup table or by performing simple calculations. Since only a small current is through the thermistor, the self-heating effect is neglected. This circuit can be used to acquire high precision measurements of the temperature of operation of the Thermistor.

Simulation Output:

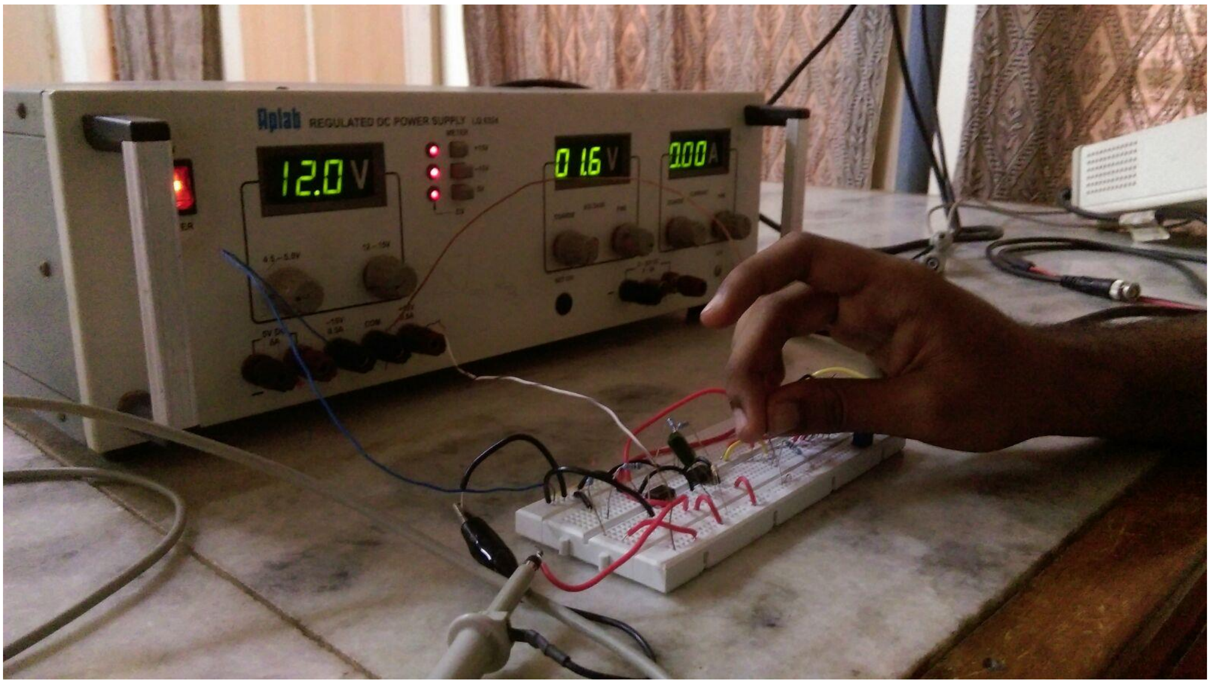
(a) At 50°C temperature



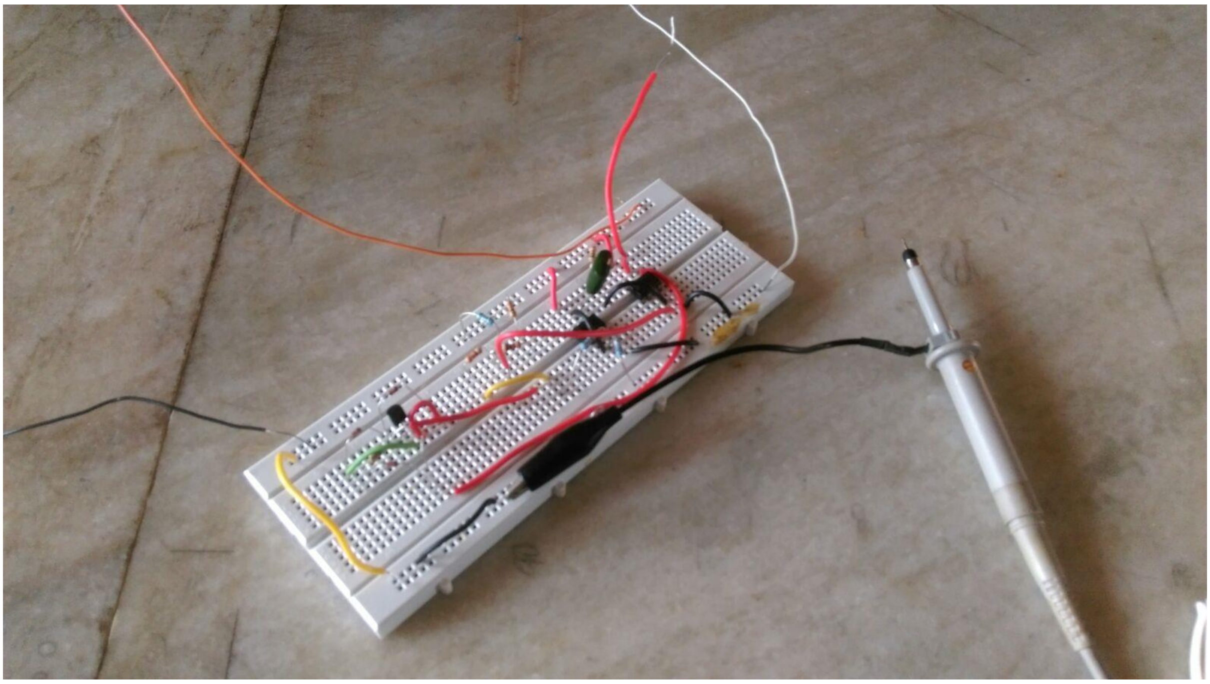
(b) At 20°C temperature



Practical Implementation



Our experimental setup with RPS

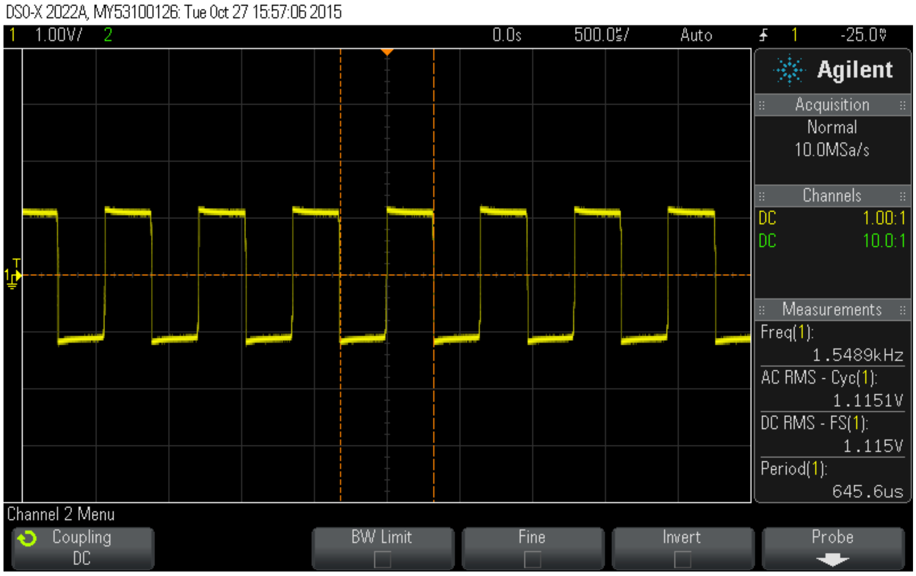


Close-up of wiring and connections

Oscilloscope Output

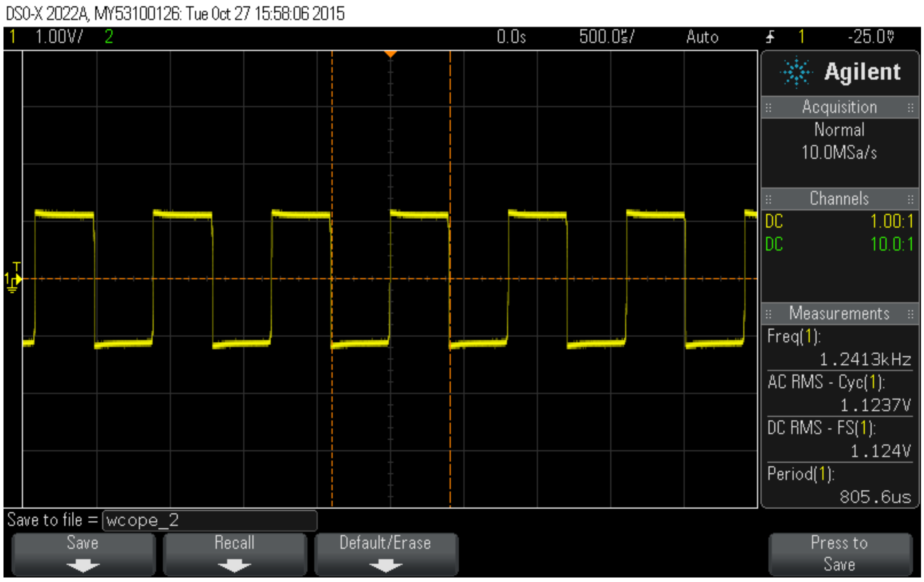
Temp: Room Temperature

Period: 645.6 µs



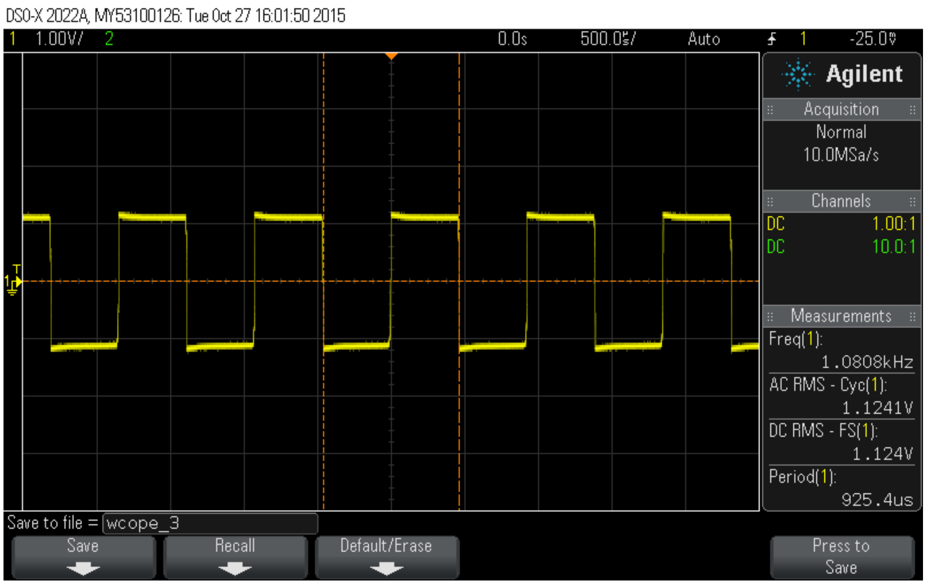
Temp: Body Temperature

Period: 805.6 µs



Temp: Heat provided by flashlight

Period: 925.4 µs



Inference and Conclusion:

The circuit to convert temperature reading from thermistor to valid frequency range is thus realized. The given output is verified to be linear and accurate within the operating range.

The output frequency varying signal can be directly sampled by microcontroller to obtain temperature to a high degree of accuracy.

Bibliography

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