Temperature Sensor For TheNet X-1J

1. INTRODUCTION

The Temperature Sensor is another addition to the "TheNet X-1J" product. Essentially a commonly available temperature sensor is used to provide a voltage which is proportional to the temperature sensed by the device. The actual device recommended (LM335Z) covers a temperature range of -40˚C to +100˚C (-40˚F to +212˚F). Other devices could be used with suitable recalibration.

This paper describes the circuit, its configuration and its operation.

2. CIRCUIT OVERVIEW

The basic structure of the circuit is shown below :

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The temperature sensor provides a voltage proportional to the temperature into the amplifier, which is set with a gain of 2. The purpose of the Offset connected to the other amplifier input, is to provide correct scaling of the amplifier output to a voltage in the full range of the ADC input (0V to 3V).

3. PORTS

The ADC ports are designated the following functions:-
ADC channel 1 - Deviation meter
ADC channel 2 - Signal strength meter
ADC channel 3 - General purpose application port 1
ADC channel 4 - General purpose application port 2

Channels 3 & 4 are general purpose application ports. Provided the user ensures that the transducers used for their particular application (wind speed, air pressure, humidity etc. all provide a signal between 0 and 3V, over their operational range, into the ADC, the ports can be configured to provide a suitable measurement/display.

For this paper I will assume that one Temperature sensor is connected to Channel 3 (application port 1) of the ADC.

4. SOFTWARE

The software reads the two application ADC ports on receiving the command "ADC". This command will return the status of the two application ports together, if enabled..

The commands associated with the application ports are;-

METER - 10 parameters for the Deviation meter, Signal strength meter & the two application ports.
ADC1 - Set up string for application port 1
ADC2 - Set up string for application port 2
ADC - returns the status of both application ADC ports.

The relevant parts of the METER parameters for the Temperature Sensor are 1,7,8,9, & 10

METER <mode> * * * * * <ADC1 scaling> <ADC2 scaling> <ADC1 offset> <ADC2 offset>

<mode> : 1 byte (Bit-wise assignments : bits 87654321)

: Bit 0 : 0=DEV meter off, 1=DEV meter enabled
: Bit 1 : 0=S-Meter off, 1=S-Meter enabled.
: Bit 2 : 0=S-Meter displays dBm, 1=S-Meter shows 'S' points
: Bit 3 : 0=ADC1 off, 1=ADC1 enabled.
: Bit 4 : 0=ADC2 off, 1=ADC2 enabled.
: Bit 5 : 0=ADC1 divisor = 100; 1=ADC1 divisor=1000
: Bit 6 : 0=ADC2 divisor = 100; 1=ADC2 divisor=1000
: Bit 7 : 0=ADC1 display Integer; 1= ADC1 fine (0.1 resolution)
: Bit 8 : 0=ADC2 display Integer; 1= ADC2 fine (0.1 resolution)

<ADC1 scaling> : 1 byte : range 0-255

<ADC2 scaling> : 1 byte : range 0-255

<ADC1 offset> : 1 byte : range 0-255

<ADC2 offset> 1 byte : range 0-255

ADC1: 7 free form bytes : user settable identifier string
Format: (e.g.) 'ADC1 V DC' (provides Volts DC)
(e.g.) 'ADC1 deg C' (provides Degrees C)

ADC2: 7 free form bytes : user settable identifier string
Format: (e.g.) 'ADC2 V DC' (provides Volts DC)
(e.g.) 'ADC2 deg C' provides Degrees C)

4.1 Application port formula

<u>Software ADC application port Formula:</u>

$$\text{Result} = \frac{[\text{<ADCp reading>} - \text{<ADCp offset>}] \times \text{<ADCp scaling>}}{\text{Np}}$$

Where :-

- <ADCp reading> is the value read from the application ADC being read
- <ADCp offset> is in the range 0 to 255
- <ADCp scaling> is in the range 0 to 255
- Np is the divisor (100 or 1000)
- p is either 1 or 2, depending which application ADC port is to be used.

Note that the intermediate result, (reading - offset) * scaling, must lie in the range -32768 to +32767. Calculations are performed in 16 bit signed arithmetic. The selectable divide by 100 or 1000 for N is to cater for occasions when this will be a problem.

5. Detailed Circuit Description.

Please refer to the Deviation Meter document for information regarding the basic operation of the circuit with respect to adding an ADC to the TNC.

The circuit employed on the temperature sensor takes into account a spare Op-Amp part left unused from the Deviation Meter hardware. Another of the four inputs of the ADC is also used. Essentially if the Deviation Meter has already been added to the X-1J node, then a temperature sensor, 3 resistors, a small pot, and a diode are all that needs to be added.

The temperature sensor (LM335Z) provides a voltage proportional to the device temperature. The table below indicates the typical voltages that can be expected across the device over its operational range. There is obviously a tolerancing variation between different devices.

The rest of the circuit is used to convert the voltage variation of 1.4V (over the 140˚C operating range) to an Op-Amp output variation of 2.8V over the same range. This variation between 0v and +2.8V is matched to the inputs of the ADC, previously arranged to full scale with a 3V input for the Deviation meter. The purpose of D2 is to clamp the op-amp output to ground if the op-amp tries to go negative.

A Calibration table appears at the end of the paper.

5.1 Parts List

QTY	REF	PART
1	R1	2K2
1	R2	51K

1	**R3**	**100K**	
1	**R4**	**10K Miniature Potentiometer**	
1	**D1**	**LM335Z (-40°C to +100°C) Temp.sensor**	**(Nat Semi)**
1	**D2**	**IN4148**	
1	**U2**	**LM324 (3rd part of original LM324 quad pack)**	
1	**X-1J R2**	**Release 2 of the X-1J TheNet software**	

6. Construction

Please refer to the Deviation Meter document for details of the original circuit construction. The temperature circuit can be added to the original Deviation meter board by adding a few components on a small piece of strip board if required, or by fitting them to the PCB underside!

7. Alignment

There are three adjustable controls that will need to be set-up for correct operation.

1) Offset voltage into pin 10 of the LM324, (R4)
2) The METER parameters 1,7,8,9 & 10
3) ADC1 string if temp sensor is fitted to application ADC1 (ADC channel 3) and / or ADC2 string if ADC channel 4 is used.

The best set-up sequence (to date) is:- (Assumes connection to ADC application port 1...

Construct complete circuit and power on **without** the ADC fitted.

Prior to fitting (or replacing) the ADC, adjust R4 to give -1.5V at the input to pin 10 of the Op-Amp. This will ensure that the Op-Amp is presenting a positive voltage into the ADC input. (The IN4148 should protect the ADC if the Op-Amp tries to swing negative.)

Measure the voltage output of the Op-Amp at a known sensor temperature. Adjust R4 to match the expected output of the circuit for the tested temperature. (Refer Calibration Table at end of paper). A thermometer may be useful at this point of the calibration to ensure an accurate setting.

Re-fit the ADC and set the METER parameters according to your requirements. The parameters used by this circuit should be (when using ADC application port 1)

Centigrade :-
'METER * * * * * * 59 * 68'
'ADC1 deg C'

Fahrenheit :-
'METER * * * * * * 106 * 38'
'ADC1 deg F'

Note that bit 3 of the first parameter must be set to enable the ADC channel.

[The -1.5V input (adjusted by R4) should ensure that the Op-Amp output range is between 0V and +2.8V across the voltage dependant temperature variation of the temperature sensor.]

8. Contacts.

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Circuit Diagram of Temperature Sensor for X-1J Release 2.

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Calibration Table

Temperature	**Temperature**	**Sensor Voltage**	**ADC input Voltage**
Centigrade	Fahrenheit		
+100˚C	+212˚F	-3.75V	+2.8V
+90˚C	+194˚F	-3.65V	+2.6V
+80˚C	+176˚F	-3.55V	+2.4V
+70˚C	+158˚F	-3.45V	+2.2V
+60˚C	+140˚F	-3.35V	+2.0V
+50˚C	+122˚F	-3.25V	+1.8V
+40˚C	+104˚F	-3.15V	+1.6V
+30˚C	+86˚F	-3.05V	+1.4V
+25˚C	+77˚F	-3.00V	+1.3V
+20˚C	+68˚F	-2.95V	+1.2V
+10˚C	+50˚F	-2.85V	+1.0V

0°C	+32°F	-2.75V	+0.8V
-10°C	+14°F	-2.65V	+0.6V
-20°C	-4°F	-2.55V	+0.4V
-30°C	-26°F	-2.45V	+0.2V
-40°C	-40°F	-2.35V	0V