Application Note: JN-AN-1264

Temperature-Dependent Operating Guidelines

When using the NXP wireless microcontroller in environments with significant temperature variation, periodic recalibration of the radio is recommended. This Application Note describes the software functions that perform these operations.

1 Introduction

The following devices

- JN5189(T)/JN5188(T)
- QN9090(T)/QN9030(T)
- K32W061/K32W041

feature an integrated radio, which is calibrated at start-up for optimum performance. In operating environments with a significant variation in temperature (e.g. greater than 20°C) due to diurnal or ambient temperature variation, it is recommended to recalibrate the radio to maintain performance.

This Application Note describes a set of software functions which measure temperature using the on-chip temperature sensor and trigger a recalibration if there has been a significant temperature change since the previous calibration.

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2 Application Scenarios

Due to the wide variation in applications for the devices, it is desirable for the developer to identify how rapidly the temperature may vary in the application operating environment. The causes of temperature variation may range from slow diurnal (Day/Night) changes (e.g. equipment located outdoors) to rapid changes when co-located equipment is switched on (e.g. lighting fixture). The rate of application data transmission and loading on the network may also be taken into account when determining the checking period for the calibration.

Once the temperature range and rate of change of temperature have been identified, the time-period for checking the calibration may be estimated. This time-period should be chosen to be less than the time taken for the ambient temperature of the chip to change by the recalibration range. For example, for an environment with temperature variation of 80^{o}C over a 12-hour period, changing by 20^{o}C in 3 hours, and so the recalibration check-time period would be set to 3 hours. In practice, a more frequent call may be made.

In lighting applications, the lamp fixtures can reach temperatures well above 100^{o}C, and therefore recalibration will be required. The application program will know when the lamp is turned on, off or if the lamp has a dimmer function, when the light level is changed. In these circumstances, the temperature sensor should be checked more frequently than when the lamp is in a steady state.

3 Radio Driver Functional Description

3.1 Requirements

- The application is responsible for reading the temperature, as the application may also want to access to the ADC
- Radio recalibration must be performed when the MAC is not using radio
- Temperature reading and MAC being idle are not co-ordinated with one another

The basic mechanism works as follows:

3.1.1 Initial Calibration

Initial calibration is performed based on input temperature T_c passed from the application during initialisation. Once calibration has completed then the temperature is stored in variable T_{cal} and clears a variable (Cal-flag) that is used to indicate if calibration is required

3.1.2 Temperature Updates

The update function stores the new temperature T_c in variable T_c. If the difference between T_c and variable T_{cal} is beyond the required threshold, sets variable Cal-flag

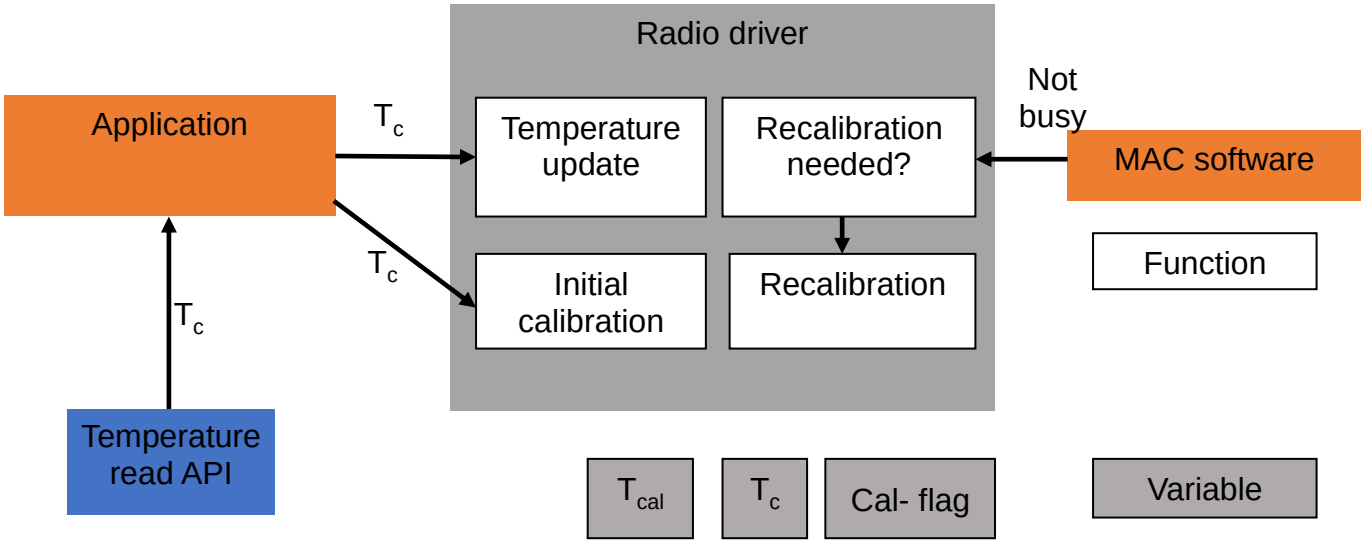
3.1.3 Recalibration

When the radio changes state (between TX and RX or from idle to either RX or TX), the Cal-flag is checked. If the Cal-flag is clear, then no recalibration is performed. If the Cal-flag is set, then the recalibration function is called. This function performs the calibration based on temperature from variable T_c. Once complete, the function copies the temperature value from variable T_c to variable T_{cal} and clears variable Cal-flag.

If the radio calibration callback *bRadioCB_WriteNVM* has been implemented in the application, then the temperature will be stored with the calibration data. This allows the radio to re-load these calibration values without requiring a new calibration if the temperature is within this defined range (+-20deg).

In BLE applications, the radio is recalibrated before the device goes to sleep and the result saved as normal. If the temperature is within the range on wakeup then no recalibration is required.

This procedure is shown in the diagram below:



3.2 Application Changes

1. The application should read the current temperature T_c at startup. If this is not done, the radio is calibrated the temperature will not be stored with the results and further recalibration will be required.
2. Temperature T_c will then be passed to radio driver during initialisation. The radio driver performs the calibration and stores temperature T_c as T_{cal}, the temperature when last calibration was performed.
3. Current temperature T_c should be read by the application every *x* seconds. The period will vary depending upon how much temperature variation anticipated by the application.
4. Temperature T_c is passed to radio driver; radio driver compares T_c to temperature T_{cal} and sets internal flag if new calibration is needed
5. MAC calls into radio driver when it is between activities; this may happen many times per second (busy network) or as rarely as once every 15 seconds (quiet network, ZigBee ping); radio driver can perform calibration if needed, and if so, it updates T_{cal} to match T_c. If no calibration needed, radio driver exits function immediately
6. Repeat steps 3 to 5 whilst running

4 Radio Recalibration Software Functions

4.1 Radio Recalibration Function

void vRadio_Temp_Update(int16_t s16Temp);

int16_t s16Temp: Temperature expressed in half of degree C (2'complement 16-bit value)

- For example, 40 (or 0x28) for 20 degree Celsius or -40 (0xFFD8) for -20 degree Celsius

This function provides the radio driver with the current temperature value. If no temperature has provided, radio driver assumes 25°C but will not store this temperature with the results. The recalibration is initiated automatically by the MiniMac when it changes state. The recalibration can be called manually by calling vRadio_Recal(). If calling manually, you must ensure that the radio is not in use. The vRadio_Temp_Update() function can be called repeatedly as the temperature varies even if no radio recalibration has taken place since the last call (the radio did not change state as no packet was received or transmitted). The next recalibration will simply use the latest temperature value as the current temperature.

void vRadio_Recal(void);

Manually perform the radio recalibration. Radio recalibration must be performed when the MAC is not using radio. This cannot be guaranteed when the Zigbee stack is running but may be known in other applications.

5 Including the Software Functions

5.1 Function Header File

The recalibration functions are included in the library **libRadio.a** which is supplied as part of the SDK libraries, as is the header file **radio.h**.

To access these library functions, you are required to include the header file in the application source code. To do this, add **#include "radio.h"** to the application source code. No modifications will be required to the makefile.

5.2 Modifying the Application

Make the following additions in your application code to implement periodic recalibration:

1. Read the temperature at startup and call vRadio_Temp_Update() before the radio is initialised.
2. Periodically, read the temperature and call vRadio_Temp_Update() from within your main loop or by using a timer.

Revision History

Version	Notes
1.0	First release

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