

TWR-KV10Z32 Thermistor Lab Tutorial

This lab will help you to understand how to configure and use ADC module to sample differential voltage across on-board thermistors RT1 – RT4. If a user touch any on-board thermistor by a finger the lab application detects a change in the thermistor temperature and start flashing the corresponding LED pair.

The Lab tutorial demonstrates:

- how to configure ADC module to read differential inputs
- how to filter and process ADC results
- how to use FreeMASTER visualization tool to display sampled results

Prepare the tower board

Short pin 1 & 2 on J11 to J14;

Short pin 2 and 3 on J8;

All other jumpers are in default states;

Download the lab code into KV10Z32 and run the lab

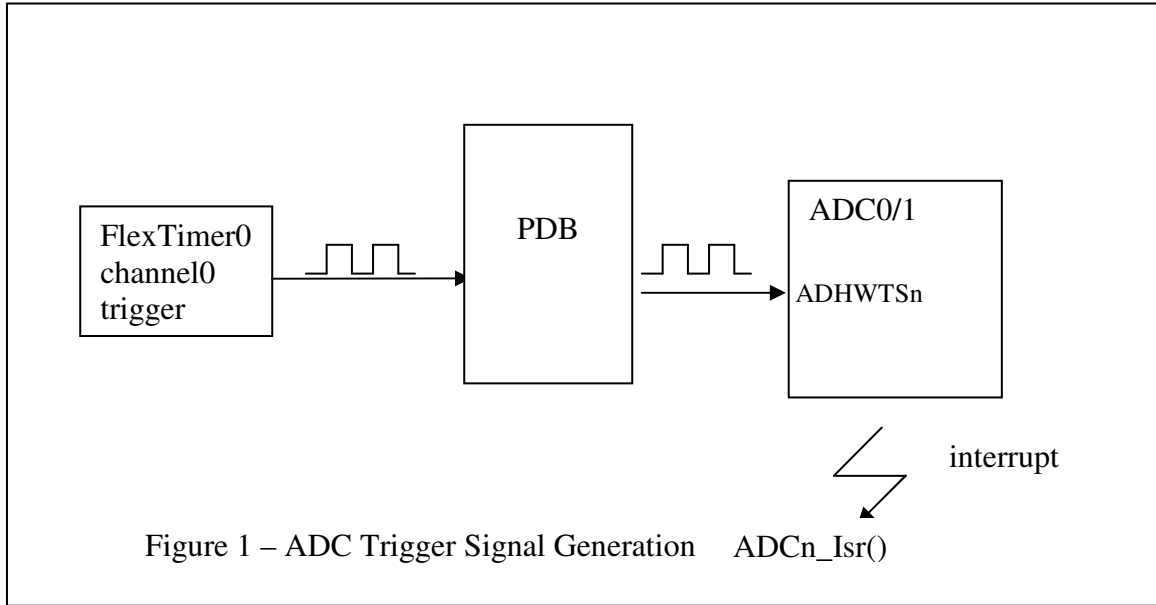
Follow the TWR-KV10Z32 Sample Code Guide for IAR, CodeWarrior or KEIL to download and run the lab code.

The text below describes an application with a FreeMASTER enabled communication.

Thermistor Lab Code Overview

The lab application configures both ADCs to be triggered by FlexTimer0 via PDB. The FlexTimer is configured to generate 16KHz PWM and the channel0 trigger is used to trigger both ADCs via PDB. The PDB is configured to generate four delayed trigger signals to both ADCs per FlexTimer0 channel0 trigger and as a result there will be 4 ADC samples converted per each FlexTimer channel trigger. The ADC is configured to be 16-bit differential mode, and in ping-pong mode.

When an ADC conversion is complete an interrupt is generated by ADC module and an interrupt service routine is executed (see Figure 1).



The interrupt service routine `ADCn_Isr()` calls `ADCn_Task` (where $n = 0, 1$) which executes following tasks:

- read ADC result registers
- filter ADC results with low-pass FIR filter
- differentiate filtered results to detect a change in a voltage across the thermistor
- detect a negative/positive slope of a voltage change to determine which LED will be turned on/off. If a negative change in a voltage is detected a corresponding pair of LEDs is switched on, flashing fast. If a positive change in a voltage is detected the LED will return to a default flashing pattern.
- executes a software timer, whose timeout period is 100ms and it resets every 400ms. The software timer is used to generate a time base for LEDs flashing.

ADC Differential Mode of Operation

To measure a voltage across the thermistors it is beneficial to configure ADC for a differential mode of operation. In differential mode the ADC measures a difference between two analog inputs. The ADC enables to select an inputs pairs, which will be treated as differential inputs. Table 1 shows an assignment of ADC channels and thermistors.

Table1: ADC input configuration

Thermistor	Differential Pair
RT1	ADC0_DP1/DM1
RT2	ADC1_DP1/DM0
RT3	ADC0_DP0/DM0
RT4	ADC1_DP2/DM2

Low-Pass FIR Filters

ADC result values measured on analog input pins are processed by a digital low-pass FIR filters. The filters use functions from CMSIS DSP library. The lab application uses four FIR filter instances, one per each thermistor. The low pass FIR filters are used to remove a high frequency noise from the thermistor signal. For more details on how to use and set-up FIR filter functions please refer to FIR demos.

Detection of a Change of Thermistor Voltage

If a person places a finger on a thermistor its temperature will rise. The temperature rise will result in a decrease of a voltage across the resistor. If the finger is removed then the temperature will decrease and voltage goes up.

To detect a change in a voltage a simple differentiators are used. The filtered thermistor voltages are stored in a buffer. Buffer size is defined by BUFF_SIZE. The differentiator calculates a difference between an actual voltage sample and a sample delayed by i_delay pointer, which points into the buffer.

```
delta_rt1 = rt1_filt - rt1_filt_buff[i_delay];
```

If the voltage across the thermistor decreases the differentiator returns a negative value. If the voltage increases the differentiator returns a positive value. If there is no change in a voltage the deviator output returns zero. The bigger the slope of voltage increase/decrease the more positive/negative value the differentiator returns. The lab application uses this information to detect if the finger is placed on the particular thermistor or if the finger was removed.

Placing/removing a finger on the thermistor is characterized by a certain slope (rate) of voltage decrease/increase. The application defines positive and negative thresholds for each thermistor.

If a differentiator output exceeds threshold limits (for at least three consequent samples) then an action is taken and a corresponding LED pair starts to flash faster. Assignment of LED pairs vs. thermistors is in a following table.

Thermistor	LED pair
RT1	LED0,LED1
RT2	LED2,LED3
RT3	LED4,LED5
RT4	LED6,LED7

FreeMASTER Visualization

The measured ADC results can be visualized via FreeMASTER.

Launch FreeMASTER application by clicking on freemaster.pmp project file in the same folder as the lab project files.

Configure COM port to the OpenSDA serial terminal port and speed to 115200 on Comm tab of Project->Options dialog.

Click STOP icon to restore communication if it is stopped.

For more details on FreeMASTER communication set-up please see **FreeMASTER demo readme.txt**.

The FreeMASTER watch window will display following variables:

- **rt1_filt, rt2_filt, rt3_filt, rt4_filt** – filtered voltage measured across thermistors in mV.
- **rt1on, rt2on, rt3on, rt4on** – show status of every thermistor. If rtxon = 1 temperature rise detected (a finger is touching the thermistor).

There are five scopes available to be displayed by FreeMASTER. The list of the scopes available can be found in a Project Tree window. The scopes are: **rt1, rt2, rt3, rt4** and **swTimer**. The **rtx** scope window display following waveforms (see Figure 2):

- **rt1** – green line – direct ADC result reading (no filter)
- **rt1filt** – red line – voltage across rt1 filtered by low-pass FIR filter

- **delta_rt1** – blue line – rt1filt signal after differentiation
- **rt1on** – light blue line – if =1 then a finger is touching thermistor rt1

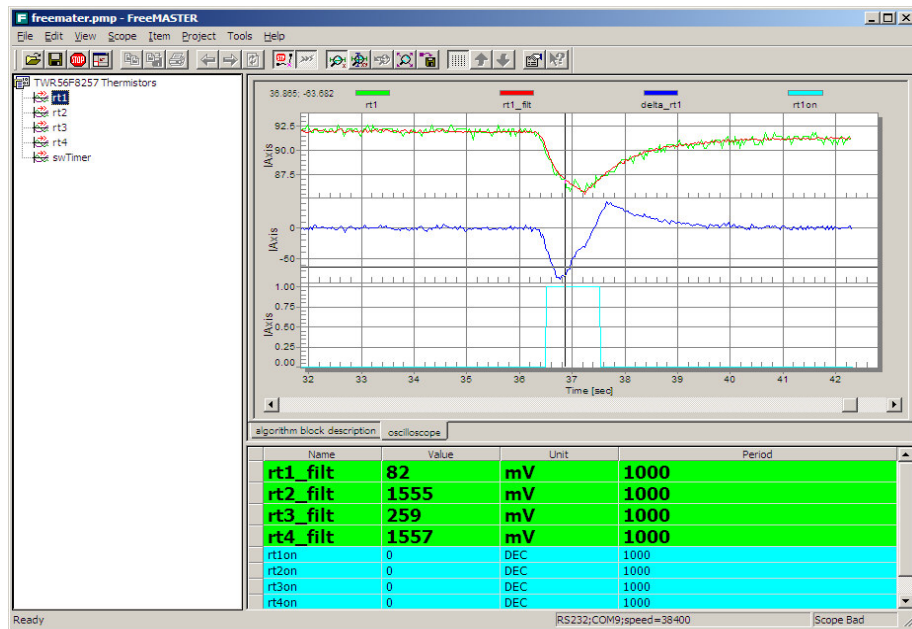


Figure 2 – FreeMASTER project page