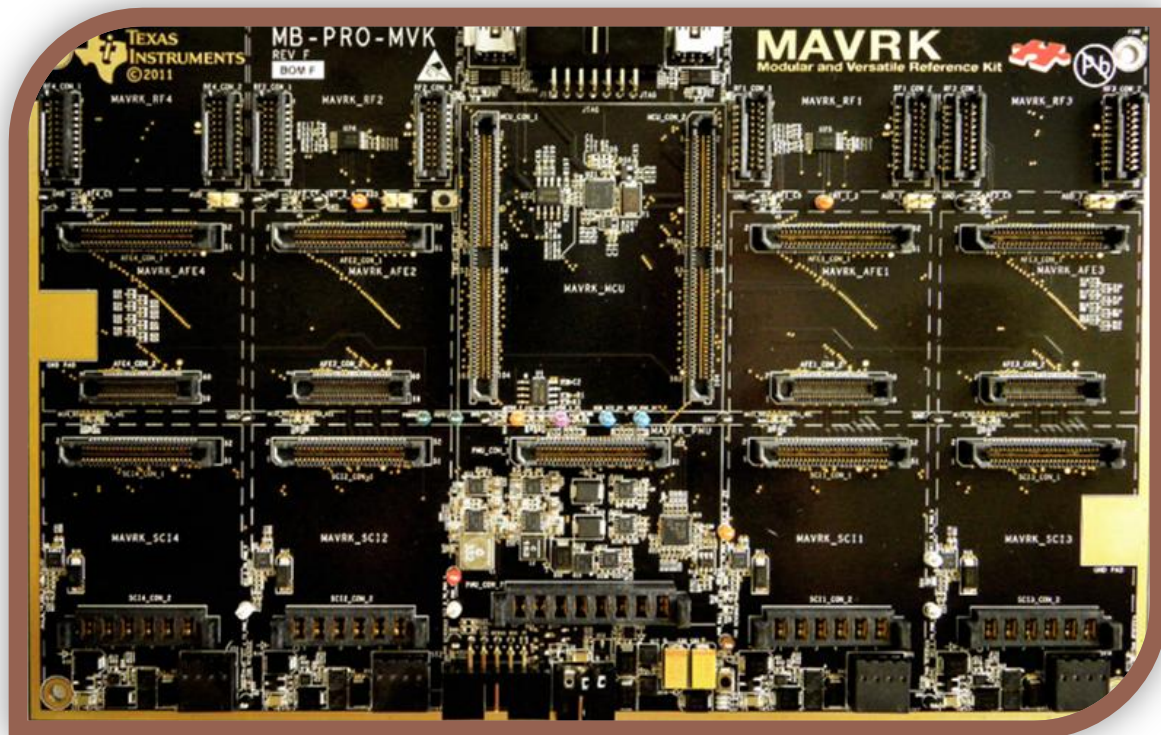


Signal Conditioning Circuit Design



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Executive Summary

Texas Instrument has recently released a new system development platform MAVRK (Modular Versatile Reference Kit). MAVRK enables its users to focus less on component level design and focus more on a system-level-design by implementing premade modules of circuits. uMAVRK is one of the modules that makes up MAVRK, and its purpose is to communicate with remote server via RF signal. It is equipped with Digital Signal processing unit CC430, RF transmitter/receiver, JTAG interface, 8-pin power module connector and 40pin serial analog interface.



Key Words : CC430, uMAVRK, CDAC-SAR

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Understanding Signal Conditioning

In engineering, signal conditioning is a process of manipulating an analog signal in such way that it is optimized for further processing. Most common example will be Analog-to-Digital Converters (Abbreviate to ADC in future use). Signal conditioning is typically categorized into three stages; Filtering, Amplifying, Isolation.

In Filtering stage, goal is to eliminate the undesired noise from the signal of interest. Usually low-pass, high-pass, or band-filter is implemented to eliminate unwanted signal.

In Amplifying stage, the goal is to increase the resolution of the input signal and increase the Signal-to-Noise Ratio (SNR). For example, the output of typical temperature sensor is in range of few millivolts and it is most likely too low for ADC to process directly. In addition, the noise within circuit is typically in range of few millivolts too, making ADC unable to distinguish between noise and signal of interest.

Lastly Isolation is a process of converting filtered & amplified signal to other form such as frequency so to pass the signal to measurement device without a physical connection. In uMAVRK module, an Isolation process is handled by built-in RF transmitter.

Circuit Design Procedure

Input Signal determination

Before any signal conditioning, the first step is to determine input signal itself. In this application note, simple RTD (resistive Temperature Detector) sensor in Wheatstone bridge configuration will be used as our input signal. Detailed calculation methods are provided in the datasheet for PTS1206 in appendix. The purpose of this circuit is to measure temperature in range from 0 to 70°C, and our input will be VDC difference between Node A and Node B. Resistor value of RTD varies from 100Ω to 127Ω which represents 0 to 70°C temperature range. By DC analysis, Voltage difference varies from 0V to 91.94mV, in steps of 3.74mV per 1Ω increase.

Restrictions applied when using Wheatstone bridge configuration to measure RTD is that we need constant voltage and very precise resistors. If there is change in supply voltage of 3V, the readings from node A and node B will also change, not knowing if the voltage change has occurred due to temperature change or increase/decrease of battery source. In addition, the change of resistance of RTD per degree is no more than few mΩ, resistors that makes up Wheatstone bridge must be in a very low tolerance range in order to get an accurate measurement. TPS61222 is an LDO(Low Dropout Regulator) that can output constant 3V for voltage input in range of 2.7V to 3.3V.

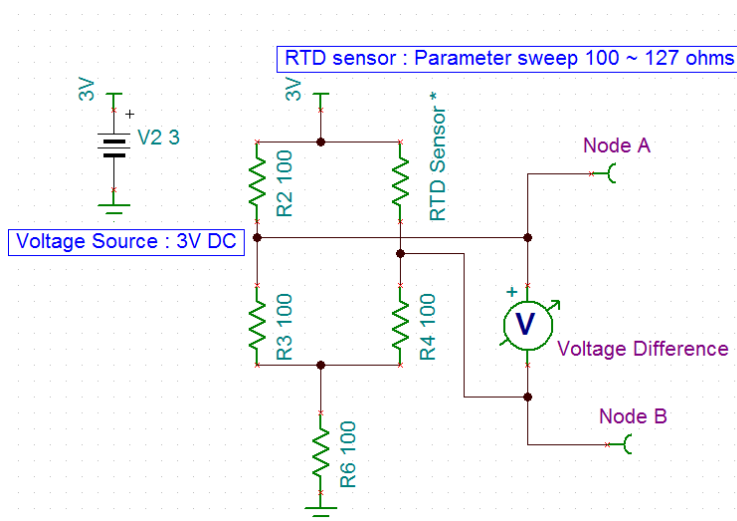


Figure1. RTD sensor circuitry with Wheatstone bridge

Amplification

Next step is to design a circuitry that can output difference between node A and node B. In this application note, INA333 (instrumentation amplifier) will be implemented for such purpose. Instrumentation amplifier is a type of differential amplifier that does not require input impedance matching through two input buffers. General characteristic of differential amplifier includes; very low DC offset, low drift, low noise, very high open-loop gain, very high common-mode rejection ratio, and very high input impedances. Instrumentation amplifiers are suited for application that requires to measure small voltage with high accuracy with minimal influence from noise.

The maximum voltage difference between two nodes is 91.94mV, so in order to increase resolution and SNR, it is best to amplify the voltage by gain of approximately 30, to match the reference voltage of ADC. The gain of instrumental amplifier is set by adjusting resistance R5 of the circuitry. However, in order for INA333 to function, there are certain conditions that need to be met. First, it is always a good practice to have supply voltage to OP amp 2V above the maximum output voltage swing, which in our case is approximately 3V. Second, both V_{in+} and V_{in-} should be kept 0.1V above ground for linear operation. These conditions may vary with different type of amplifier chosen.

Resistor R6 at the lower portion of Wheatstone bridge insures that both V_{in+} and V_{in-} stay 0.1V above ground, with common-mode voltage (voltage measured at two nodes when there is zero difference) 2.25V. Also, to supply 5V to $V+$ of INA333, TPS60140 DC to DC booster is implemented into the circuitry.

In practice, capacitance is set to be at least bigger than 20 times ADC input capacitance. Input capacitance of CC430 is 25pF which makes external capacitance value to be at least bigger than 0.5nF. In this application note, we will pick 1nF as our external capacitance.

The next step is to determine value of external resistance. Value of external resistance is determined by following equation:

$$0.6 \times \text{Acquisition time} \geq k \times R_{FLT} \times C_{FLT}$$

The acquisition time is being multiplied by factor of 0.6 to give margin for Op Amp output load transient and small signal settling time. Using capacitor value of 1nF with other parameter, external resistance has to be at least larger than 398 ohms.

After determining RC filter, appropriate buffer amplifier needs to be chosen. Buffer amplifier can be either in voltage follower or inverting amplifier configuration. In this application note OPA363 from TI is chosen as buffer amplifier. It has very low CMRR (Common mode rejection ratio) and optimized to be used as a driver for ADC input capacitance. Figure 3 illustrates signal conditioning circuitry with OPA363 and RC filter applied.

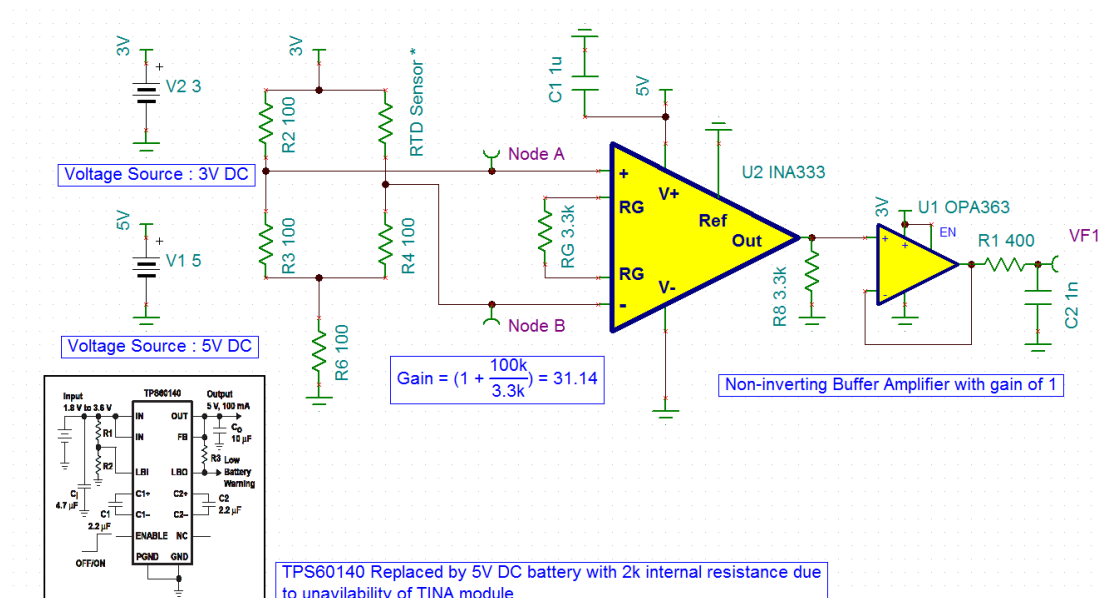
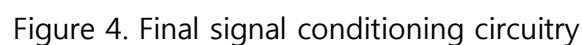


Figure3. Circuit with CDAC-SAR ADC drive

One Important characteristic of uMAVRK is that it is a remote device that can communicate through wireless interface via RF. It is usually powered up by limited power source such as battery. In order for the module to run for long period, power efficient design is critical. One approach is to use switch circuitry to enable/disable the entire device via GPIO (General Purpose Input/Output) of uMAVRK. Implementing enable/disable pins reduces quiescent current being constantly drawn, thus increase power span of the device. Our 5V DC-DC step up booster and OPA363 already has an enable pins in their integrated circuitry, so making connection between enable pin and GPIO is sufficient. However, 3V power source to our Wheatstone bridge circuitry and INA333 constantly draws 16.68mA of current, so extra circuit component needs to be added to block these current for device in idle state. Figure 4 indicates final signal conditioning circuitry.



Appendix I – Datasheets

CC430F5137 – MSP430 SoC with RF core

www.ti.com/product/cc430f5137

TPS60140 – Low power DC-DC Converter Regulated 5V, 100mA Charge Pump Voltage Tripler

www.ti.com/product/tps60140

TA5A3166 - 1-Ohm SPST Analog Switch 5-V/3.3-V Single-Channel Analog Switch

<http://www.ti.com/product/ts5a3166>

INA333 – Low Power Precision Instrumentation Amplifier

www.ti.com/product/ina333

PTS1206 – Platinum SMD Flat Chop Temperature Sensor

www.vishay.com/docs/28762/28762.pdf

OPA363 – 1.8V, High CMR, RRIO OP Amp with Shutdown

www.ti.com/lit/ds/sbos259b/sbos259b.pdf

Appendix II – Time Constant Multiplier

Number of bits	0.5LSB	Time Constant Multiplier(k)
10	0.0488281%	8
12	0.0122070%	9
14	0.0030518%	11
16	0.0007629%	12
18	0.0001907%	13
20	0.0000477%	15
22	0.0000119%	17
24	0.0000030%	18