Temperature Sensors

There are several common types of temperature sensors, namely, semiconductor (silicon) type, thermistors, resistive temperature devices, and thermal couples. The output signals of the sensors can be in various formats such as analog voltage output, serial (SPI or IIC) output, or logic output. A semiconductor type temperature sensor with analog voltage output will be discussed in this subsection. The particular temperature sensor is LM34CZ. This is a temperature sensor for general purpose applications.

This section shows how to connect the temperature sensor to the CSM-12C32 module and provide the C-codes for initializing the on-chip analog-to-digital converter for capturing the analog output voltage from the temperature sensor. Pictures, ordering information and web link of the datasheet are shown below.

<table>
<thead>
<tr>
<th>Vendor</th>
<th>Part Number</th>
<th>Weblink for the part</th>
<th>Description</th>
<th>Unit Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hobby Engineering</td>
<td>LM34CZ</td>
<td>LM34CZ TEMP</td>
<td>Precision temperature sensor: analog voltage output</td>
<td>$6.50</td>
</tr>
</tbody>
</table>

Hardware interfacing to the Freescale 9S12C32 MCU

As shown in the diagram above, there are three pins in the package. The power supply is connected to pins Vs and GND. Consult the datasheet for the acceptable range of Vs. The pin Vout is the analog output voltage pin and is to be connected to the analog-to-digital converter. The resolution of the temperature sensor is 10 mV/°F. For instance, at 72 °F, the analog output voltage is 0.72 V. For a narrow range of temperature sensing, an optional amplifier for increasing the output voltage level is recommended. The non-inverting amplifier structure can be used. The circuit diagram is shown below. The gain of the amplifier is 1+R2/R1. The resistance R1 and R2 are to be selected so as to achieve your desired gain. It is recommended that the resistors be of 1% accuracy or better so that the gain factor can be more accurate. The operational amplifier can be a general purpose type such as 741 or precision type.
**Software development**

A code snippet in C below can be used for initializing the ADC of the MCU to interface with the LC34CZ. It is assumed that the analog voltage is fed to the channel 0 of the ADC module. Other assumptions are included in the comment statements. The code snippet can be easily modified for other conversion settings.

```c
void initADC(void) {
    ATDCTL2 = 0x80;   // turn on ADC  ATDCTL2_ADPU=1
    ATDCTL3 = 0x08;   // 1 conversion/sequence
    ATDCTL4 = 0x01;   // 10-bit conv., 2Mhz ADC clock (assume bus clock=8MHz),
                     // fastest conv.
    ATDCTL5 = 0x80;   // right justify, unsigned, non-scanning,
                     // non-multichannel
    return;
}
```

Note that 10 bit resolution is recommended. Such resolution is 5 mV per bit. If a gain factor of 2 is used for amplifying the analog output voltage of the LM34CZ, the resolution for temperature is 0.25 °F per bit. The resolution can be higher if the gain factor is larger.

A C function for reading the analog voltage is shown below. The delay for 1 ms in the function is to give sufficient time for the ADC to finish the conversion. Every execution of this function will result in a new temperature reading stored in the variable temperature.

```c
void readTemp(void) {
    short temperature;

    ATDCTL5 = 0x80; // initiate ADC conversion
    waitms(1);      // delay 1 ms, this function was covered in class
    temperature = ATDDRO; // read temperature
    // note that for right justified data, there needs not the
    // instruction temperature >> 6 for left justified case
    return temperature;
}
```