Application Note AN2028

Ohmmeter

By: Dave Van Ess
Associated Project: Yes
Associated Part Family: CY8C25xxx, CY8C26xxx

Summary
A topology for an ohmmeter is shown that exploits the PSoC™ Analog Input Multiplexer. This circuit is designed to have its overall accuracy determined by a single inexpensive external resister. Sample rate is selected to minimize any power line interference (normal mode rejection).

Introduction
Many sensors are transducers that convert some physical parameter to resistance. Be it either a strain-gauge or thermistor, it is necessary to be able to accurately and inexpensively measure resistance using circuitry built with less than perfect components. Gain and offset errors can significantly limit the accuracy of ohmic measurements. This Application Note shows how error terms are eliminated and resistance can be measured with a PSoC microcontroller. A primer is also included to help better understand the process of measuring ohms.

This application uses the following PSoC microcontroller resources:

- ACDINC12 User Module
- PGA User Modules
- 2 Analog Output Buffers

Reading Ohms - A Primer
Unlike measuring voltage or current, measuring a passive quality like resistance for calculation requires a stimulus. Two qualifying stimuli are:

- A current stimulus to measure a voltage
- A voltage stimulus to measure a current

One method of measuring resistance is to, quite literally, push a know current through a resistor and measure the voltage across the resistor. Figure 1 shows how this is done.

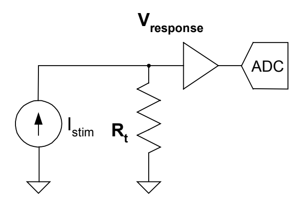

Figure 1: Current Stimulus Block Diagram

Equation (1) shows how resistance is calculated:

$$R_t = \frac{V_{response}}{I_{stim}} \quad \textbf{(1)}$$

This method of measuring ohms has the advantage that with the correct selection of I_{stim}, no math is required. This method was very popular when the cost of computation was more than the cost of building an accurate current source. It also has two drawbacks. First, the accuracy of the reading is directly limited by:

- The accuracy of the current source
- Any gain or offset errors from measuring $V_{response}$

Second, the range of measure is limited to the ADC's signal range as shown in Equation (2).

$$R_t(\max) = \frac{V_{response}(\max)}{I_{stim}} \quad \textbf{(2)}$$

With the development of more powerful microcontrollers and on-chip ratiometric ADCs, the architecture shown in Figure 2 became a more inexpensive solution.

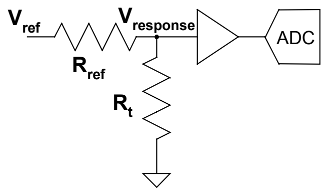

Figure 2: Resistive Divider Block Diagram

Equation (3) shows how the resistance is determined:

$$R_t = R_{ref} * \frac{V_{response}}{V_{ref} - V_{response}} \quad \textbf{(3)}$$

This architecture has the advantage of having a range of measurement that is theoretically short circuit to open circuit. The actual range is limited by any offset error from measuring $V_{response}$. The overall accuracy is limited by:

- R_{ref}
- Gain and offset errors from measuring $V_{response}$

The error introduced by R_{ref} is controlled primarily by its cost. The reference voltage V_{ref} can be taken from supply voltage, V_{cc}. The gain error of a ratio-metric ADC is generally small and does not contribute much to the overall error. Not so, with the offset error. The offset error can be the largest contributor of error to the overall accuracy. This error is generally reduced with the application of money to reduce the offset error of any op-amps in the measurement path.

Reading Ohms the PSoC Way

Figure 3 shows how the PSoC Output Buffers and Input Multiplexer are connected to significantly remove gain and offset errors:

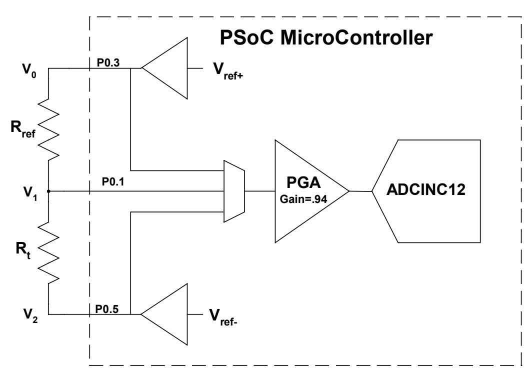

Figure 3: High Level Block Diagram

Equation (4) shows how the resistance is determined:

$$R_t = R_{ref} * \left(\frac{V_1 - V_2}{V_0 - V_1} \right) \quad \textbf{(4)}$$

As shown in Equation (4), any offset errors in the measurement system are removed by the subtraction of two measured voltages. The ratio of these two difference values removes any measurement path gain error. This leaves the measurement error to be determined by:

- R_{ref}

This is valid as long as the measured signal is never outside the range of the ADC. To guarantee this the sense buffer is set for a gain slightly less than unity. As stated earlier, the accuracy of R_{ref} is determined by cost. The user makes the trade off between R_{ref} cost and accuracy in his application.

Special Feature – Conductance

Some transducer outputs are better expressed as a conductance (G) instead of a resistance. A simple juggling of Equation (4) results in Equation (5) to determine conductance:

$$G_t = \frac{1}{R_t} = \frac{1}{R_{ref}} * \left(\frac{V_0 - V_1}{V_1 - V_2} \right) \quad \textbf{(5)}$$

Multiple Channels

Figure 4 shows how multiple resistors can be measured. With 8 analog pins on Port 0, it is possible to measure up to 6 different transducers.

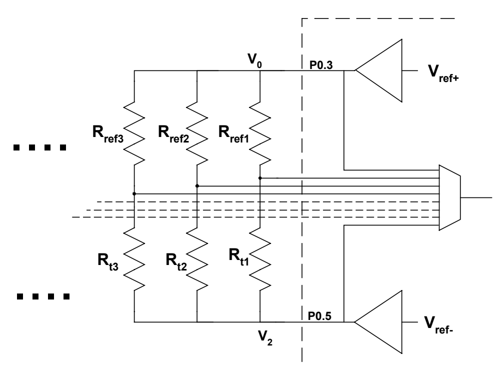

Figure 4: Multiple Sensor High Level Block Diagram

The example in Figure 4 has all the sense paths multiplexed to a single buffer and ADC. A variation would be to connect each of four sense paths to its own buffer and ADC. The PSoC architecture allows the synchronous operation of up to four ADCs. An example of a possible application would be a tri-axial accelerometer.

Sample Project

A copy of the project associated with this Application Note is available on our web site. For this project, R_{ref} is set to 10 kΩ. Figure 5 shows the User Module placement.

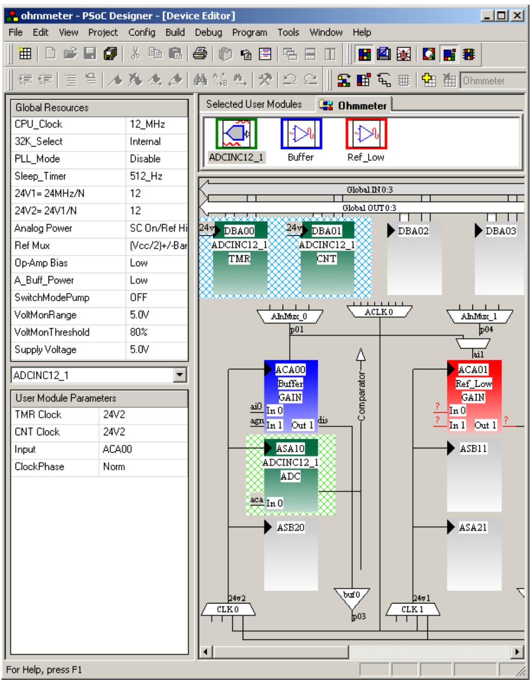

Figure 5: Ohm Meter User Module Placement

The buffer is a **PGA** User Module placed in ACA00. It is connected to the multiplexer that connects its input to Port 0[1]. Software will be added to enable the ACA00's testmux to connect V_{ref+} to the column 0 analog bus. Buf0 brings this reference out to Port 0[3].

A second **PGA** is placed in ACA01 as a placeholder. The gain stage is not used. The sole purpose is to allow access to the testmux. Software will be added to enable ACA01's testmux to connect V_{ref-} to the column 1 analog bus. Buf1 brings this reference out to Port 0[5].

The analog block of the **ADCINC12** is placed just below the buffer. The clock for the ADCINC12 is set to 167 kHz for a sample rate of 10 sps. This sample rate causes any 60 Hz or 50 Hz interference to be removed from the signal. The sample rate can be increased if the application requires a faster conversion.

The control software is written in C. The resistance reading is calculated and left in a global memory location. The reading for this example, `rAnswer`, can easily be viewed with the ICE by setting a breakpoint just after the point where the calculation has been completed. Bringing the data out of the chip is an exercise left to the user.

```
//-----------------------------------
//  Ohm Meter
//
//  This program reads the value of
//  3 different voltages to determine
//  the ratio between Rt and Rref
//
//-----------------------------------
#include "m8c.h"
#include "ADCINC12_1.h"
#include "Buffer.h"
#include "Ref_Low.h"

int iV0, iV1,iV2;
float rAnswer;

void main(){
   Ref_Low_Start(Ref_Low_HIGHPOWER);
   Buffer_Start(Buffer_HIGHPOWER);
   ADCINC12_1_Start(ADCINC12_1_HIGHPOWER);

   ACA00CR2 |= 0x1c;  //set testmux to ref+
   ACA01CR2 |= 0x08;  //set testmux to ref-

   while(1){
      //Reading V0 (Vref+)
      AMX_IN =(AMX_IN & 0xfc)| 0x01; //P0.3
      ADCINC12_1_GetSamples(1);
      while(!ADCINC12_1_fIsData());
      iV0 = ADCINC12_1_iGetData();

      //Reading V1 (Signal)
      AMX_IN =(AMX_IN & 0xfc)| 0x00; //P0.1
      ADCINC12_1_GetSamples(1);
      while(!ADCINC12_1_fIsData());
      iV1 = ADCINC12_1_iGetData();

      //Reading V2 (Vref-)
      AMX_IN =(AMX_IN & 0xfc)| 0x02; //P0.5
      ADCINC12_1_GetSamples(1);
      while(!ADCINC12_1_fIsData());
      iV2 = ADCINC12_1_iGetData();

      rAnswer =((float)(iV0-iV1))/((float)(iV1-iV2));
      //Answer can be viewed here with the ICE
   }
}
```

Conclusion

The right circuit topology makes it possible to eliminate most error terms while measuring ohms, leaving the accuracy to be determined by a single reference resistor. The PSoC microcontroller, with its Analog Output Buffers and input multiplexer, makes it an ideal choice for measuring resistance.

Cypress MicroSystems, Inc.
22027 17th Avenue S.E. Suite 201
Bothell, WA 98021
Phone: 877.751.6100
Fax: 425.939.0999
http://www.cypressmicro.com/ http://www.cypress.com/aboutus/sales_locations.cfm support@cypressmicro.com