Digitalisation Of A Peak Voltmeter Display And Subsequent Error Minimisation Using Polynomial Compensation Technique

Hiya Roy, Jadavpur university, Electrical engineering.
Subhajit Chaudhury, Jadavpur university, Electrical engineering.

Abstract

The proposed scheme proposes an idea of processing the low voltage output from a peak voltmeter and displaying its analog equivalent in a suitable display device after suitable minimization of error. The PIC voltmeter is used to measure voltage ranging from few Kilo Volts to few hundred Kilo Volts. A capacitive divider is used to step down this high voltage to few volts which is suitable for measurement and instrumentation purpose. The scheme uses a PIC 18F4550 microcontroller for Digital to analog conversion and hardware interfacing with the peak voltmeter circuit. The error minimization is achieved by using a lagrangian polynomial approximation technique which performed by the PIC microcontroller itself.

1. Introduction

The peak voltmeter measures the peak voltage of a sine wave. The concerned peak voltmeter was originally accompanied by an analog display device. The current Peak Voltmeter display system uses a reduced voltage level by a capacitor divider circuit. The idea proposed by the current scheme is mainly to replace the analog display by its digital counter-part. The circuit which is used to achieve the digital output consists of non-linear circuit elements like transistors, diode and passive elements like resistors and capacitors. These elements are prone to produce thermal noises in the output signal, thereby introducing severe distortion in the output voltage value. Further these thermal drifts are temperature and voltage sensitive and hence vary with various room temperatures and output voltages.

In order to reduce the effect of errors a suitable compensation technique is adopted. Here an improved Lagrangian error function interpolation algorithm is used. The present system is calibrated in the laboratory conditions of Jadavpur University High Voltage Laboratory. Data from uncompensated microcontroller based system is taken and tallied with the actual reading from the actual analog peak voltmeter. Thereby the error for corresponding output voltages of the uncompensated system is found and a fitting polynomial for error vs output voltage is calculated, where from the corresponding errors at the desired output values of the uncompensated microcontroller based system is obtained. The error so found is subtracted from the uncompensated value to obtain the corrected result at the output. The present system is calibrated in the laboratory conditions of Jadavpur University High Voltage laboratory.

2. Overall scheme of the proposed work

The scheme of the process is shown below:

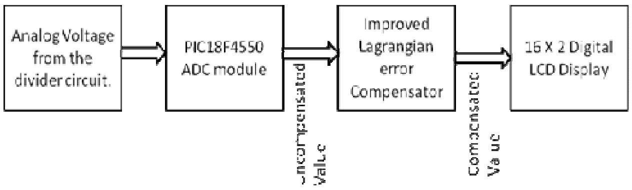

Fig 1: Basic Scheme of the proposed Digital Peak Voltmeter

3. 10 bit ADC module and Digital Display

The output from the peak voltmeter is fed to the PIC 18F4550 microcontroller. The PIC micro controller has in-built ten bit analog to digital conversion module. This in-built ADC has eight channels for analpg input and the analog voltage is fed to analog channel 1 of the PIC18F4550 microcontroller and the corresponding digital output is processed by the microcontroller code into a form which is suitable for the display device. Here the display device used is JHD162A LCD 16 X 2 character display. The JHD162A takes 8 bit character input, which is processed by its in-built HITACHI controller to be displayed in the LCD display. Hence the digital message is decoded into suitable 8-bit form, after suitable polynomial compensation which is then fed to the LCD display device.

4. Error Minimization using Polynomial approximation (Improved Lagrangian Interpolation)

The error minimization is carried out by an improved version of Lagrangian Polynomial Interpolation. The Lagrangian polynomial for fitting a function **p(x)** such that its value at discrete points is given by :

$p(x_j) = f_j$ $\quad j = 0, 1, 2, \ldots N$ …… (1)

In such a situation it is necessary to find a continuous polynomial function **p(x)** such that the above condition is satisfied. Classical Lagrangian polynomial function of order n is given by,

$$p(x) = \sum_{j=0}^{n} f_j \ell_j(x), \qquad \ell_j(x) = \frac{\prod_{k=0,\,k\neq j}^{n}(x - x_k)}{\prod_{k=0,\,k\neq j}^{n}(x_j - x_k)}.$$

……………. (2)

But the classical lagrangian interpolation has few drawbacks: Each evaluation of p(x) requires n^2 additions and multiplications(where n is the number of iterations), addition of new data pairs requires re-evaluation of *p(x)* and the method introduces numerical errors. Thus an improved version of lagrangian interpolation is adopted which is as follows, if

$$\ell(x) = (x - x_0)(x - x_1)\cdots(x - x_n)$$

……………… (3)

If w_j is referred to as weights independent of function values f_j then,

$$w_j = \frac{1}{\prod_{k\neq j}(x_j - x_k)}, \qquad j = 0, \ldots, n,$$

……………. (4)

Hence from eqn (2) **lj (x)** can be denoted as

$$\ell_j(x) = \ell(x)\frac{w_j}{x - x_j}.$$

………………. (5)

Thus the interpolating function *p*(*x*) can be written as,

$$p(x) = \ell(x)\sum_{j=0}^{n}\frac{w_j}{x - x_j}f_j.$$

……………. (6)

This method requires n^2 FLOPs for calculating w_j, a quantity independent of x and n FLOPs for evaluation of the interpolating function *p*(*x*) after the values of the functions are known(n being the number of iterations).

The weights are independent of the function values fj and hence data updating is quite easy as compared to the classical approach.

Due to afore mentioned advantages, the improved lagrangian Interpolation is used as error minimization technique in the current scheme.

The algorithm for the calculation of weights from eqn, (4) and (5) can be depicted as :

$w_j = w_j^{(n)},\ j = 0, \ldots, n$:

$w_0^{(0)} = 1$
for $j = 1$ **to** n **do**
  for $k = 0$ **to** $j - 1$ **do**
    $w_k^{(j)} = (x_k - x_j)w_k^{(j-1)}$
  end
  $w_j^{(j)} = \prod_{k=0}^{j-1}(x_j - x_k)$
end
for $j = 0$ **to** n **do**
  $w_j^{(j)} = 1/w_j^{(j)}$
end

5. Data collection and System finalization.

Firstly without implementing the error minimization technique, the output from the microcontroller based digital display is recorded. In this stage, the system is basically uncompensated one. Then errors in these readings are obtained by subtracting them from the actual readings obtained from the analog peak voltmeter. In such condition a set of data of **error vs. corresponding output voltage** is obtained from this uncompensated system at the laboratory condition. A small collection of such data which are taken from the present system, calibrated in the laboratory conditions of Jadavpur University High Voltage laboratory are shown in the following table.

Table 1: Showing Performance of Uncompensated System.

Sl No	Output Voltage(KV)	Actual Output(KV)	Error in reading(KV)
1	5.4	5.2	0.2
2	10.5	10.1	0.4
3	15.9	15.3	0.7
4	21.4	20.3	1.1
5	26.4	24.8	1.6
6	32.0	30.1	1.9
7	37.6	35.0	2.6
8	43.1	40.2	2.9

In the following steps occur to obtain the final compensated output :

a) The analog voltage received from the voltage divider circuit and the corresponding digital value in calculated by the ADC module.

b) This digital value is fed to the error interpolating function from where the error at that voltage is calculated.

c) The calculated error is subtracted from the calculated digital value and the resultant compensated output is processed to a form suitable for display in JHD162A LCD display.

Firstly, from the collected data and using the above Improved Langrangian method, the entire data set in interpolated and hence the fitting polynomial is found in Matlab. Once the interpolating polynomial is obtained, it is implemented in the microcontroller code and the error at any suitable output voltage can be easily calculated.

The following figure shows the interpolated error vs. output curve.

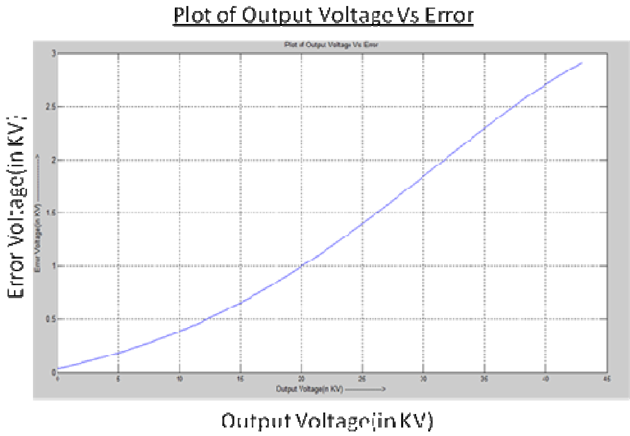

Fig 2: Plot of Output Voltage Vs Error

Once the interpolating polynomial is obtained, the error at the corresponding uncompensated output is found out at subtracted from the this uncompensated value to obtain the corrected result. The corrected is result is then compared with the true value of the analog device to depict the performance of the overall system.

Such a comparison is made in the following table.

Table 2: Showing Performance of Uncompensated System.

Uncompensated output(kV)	Compensated output(kV)	Actual Output(kV)	Deviation from actual(kV)
5	4.8185	4.8	0.0185
10	9.6167	9.5	0.1167
15	14.3469	14.2	0.1469
20	19.0054	19	0.0054
25	23.6011	23.5	0.1011
30	28.1556	28	0.1556
35	32.7032	32.6	0.1032
40	37.2909	37.1	0.1909

Average absolute error = 0.1048 KV

Mean square error = 0.3422 KV

As seen from the above data that the system when calibrated in terms of the laboratory conditions give satisfactory results without much deviation from the actual voltage. Thus a marked improvement in the output is obtained after the application of the polynomial compensation technique. Thus this method of polynomial compensation can be safely adopted for serving the purpose of current scheme

6. Conclusion

The present system is calibrated in the laboratory conditions of Jadavpur University High Voltage laboratory. But it is expected that the Peak Voltmeter may function satisfactorily as the deviation in the results due to thermal drifts in other environmental conditions are negligible for this particular scheme.

This system of polynomial compensation is based on interpolation technique, and may not work well if extrapolation is employed. Hence data collection and curve fitting must be carried up to the highest possible voltage to be measured by the Peak voltmeter. In such a case, any consequent voltage to be measured by the peak voltmeter will lie within the data brackets and can be safely interpolated avoiding the risk of extrapolation.

7. References

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