XVI IMEKO World Congress
Measurement - Supports Science - Improves Technology - Protects Environment ... and Provides Employment - Now and in the Future
Vienna, AUSTRIA, 2000, September 25-28

STUDY OF FAST FLOAT POINT 10-12 BIT AD CONVERTER

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Abstract: Discretisation error is responsible for one of major metrological problems concerning digital instruments such as AD converters. Designing the device of stable relative error would provide the ideal solution. The aim of this work is to introduce the problem and propose the float point AD converter with variable gain amplifier (VGA) as a solution.
The proposed fast setting gain with flash AD converter as a coarse one is the new approach. The conversion consists of two stages coarse and fine one. The VGA works as pre-processing circuit for fine conversion. The VGA gives the stable signal value according to the coarse conversion. In result the relative error of conversion is stable. Programmable correction of the gain will be presented. The results of simulation confirm the measurement error stabilisation and high frequency operation.
Keywords: AD conversion, discretisation error, float point conversion.

1 INTRODUCTION

The standard AD conversion in digital devices as voltmeters, ampermeters and multimeters is applied. It means that there is range set circuit and AD converter. The range should be set manually or automatically also the number of ranges does not exceed 4-6. The measurement error is described below:

$$\delta = \delta_A + (D/X)\ 100\% \qquad (1)$$

where: δ - measurement error,
δ_A - analog error of AD conversion,
D - discretisation error (+/- 1 last digit)
X - measured signal value.

The data sheet of an instrument consists of ranges and δ_A. It means that the user should calculate relative discretisation error (D/X) themselves. Figure1 shows the measurement error of an multimeter Metex M-4650 with 4 ranges (DCV) and R_d = 1/10 (range degree).

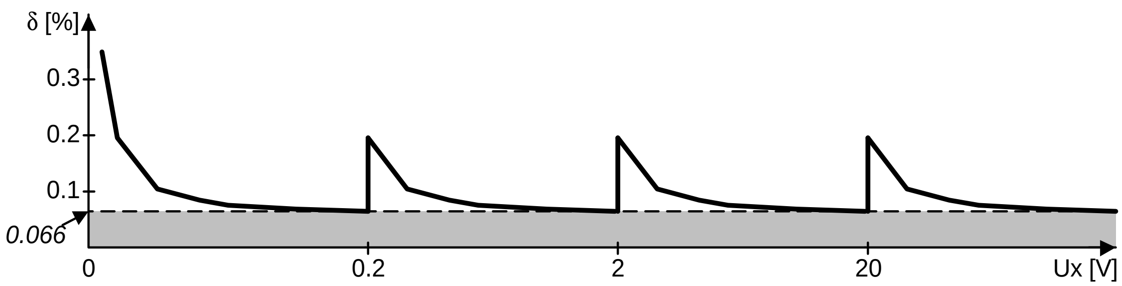

Figure 1. Measurement error of multimeter Metex M.-4650 (δ_A = 0.05%)

The relative error exceeds value 0.1% due to discretisation error for relatively small signal on the beginning of each range (fig.1). The AD converter of multimeter is ready to work with 0.07% but the range degree is too large ($R_d = U_{min}/U_{max}$). On the other side the large number of ranges (more than 5 f.eg.) will complicate the service and construction of device.

The aim of this work is to describe the error curve as above and show the solution according to desired error value. The grey surface in Figure 1 shows the correct and stable measurement error for temporary and modern measurement devices as multimeters (without any ranges).

2 PRINCIPLE OF OPERATION

There are a lot of examples for e.g. [2,3] in the literature and catalogues [4] but there is no purpose for reducing and stabilising the measurement error. In the proposed study the float point AD converter (FPC) with variable gain amplifier (VGA) is presented in fig.2.

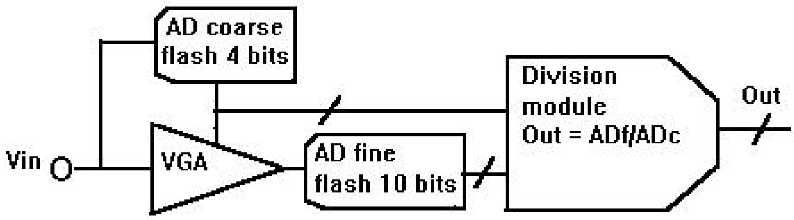

Figure 2 Float point AD converter

The difference lies in 16 up to 1024 gains (practically) of input amplifier (VGA) in opposite to 4 - 6 ranges in standard multimeters. It means that instead of a few ranges there are 1024 ones. It works as the **variator** [1] in opposite to the **standard gear box** if the mechanical solution is concerned. The system with VGA can cover the desired range of conversion without any range switches.

The loop for setting the right gain works traditionally via digital system as microprocessor one. That one calculates the result and gives the right range setting. In case of study of 10-12 bit FPC the flash 4 bit ADC (as coarse converter) is supposed for setting as fast as possible the gain instead of the loop via microprocessor (***new***).

The results: gain (G) and readout of fine converter (F) should be send to the microprocessor or to the special operation circuit (as Shark module) for fast result calculating:

$$R = F/G \,, \qquad (2)$$

where: F - result of fine conversion,
G - digital value of the gain.

In this case there is no need the high accuracy for the coarse converter. The desired accuracy will be obtained during calibration process. The thermal and time stability is important. Conversion accuracy depends on accuracy of the VGA gain (G) and fine conversion (F) directly from (2):

$$\delta R = \delta F + \delta G. \qquad (3)$$

The error of conversion (fig.1) is visible in broken line and grey surface. It is almost stable thanks to VGA operating and below 0.066% error value. That one operates between:
$15/16 < X < 16/16$ of range the fine ADC for 4 bit coarse ADC. The discretisation is still +/- 1 digit but relative value is stable thanks to coarse ADC and VGA operating ($\boldsymbol{X}$ ~ **const**), fig.1.
The error of fine conversion:

$$\delta = \delta A + (D/X)\ 100\% < 0.066\%, \text{ where: } 1/16\ Um<X<Um \qquad (4)$$

where δA is an analog error of fine conversion and gain error (temperature, time) which does not depend on input signal value. The error of the gain depends on quality of VGA but it is stable and does not depend on the result of conversion. However, the dynamic error depends also on parameters of VGA. The result is stabilisation of relative measurement error δ without cogged characteristic.

The idea of Float Point Conversion is to reduce the discretisation error and keep it on a stable level. The FPC (float point converter) takes the name from the division operation (2) which gives the result with float point arithmetic (FPA) installed in AD converter. The FPA replaces the range set switches and conditioning the signal for fine conversion.

The FPC requires the little intelligence in the converter as division operation. It is possible to multiply the result by correction factor *ki* :

$$R = (Fi / Gi)\, ki. \qquad (5)$$

in this case it is possible to apply the programming calibration. The automated calibration is indispensable if there are many values of the gain (for eg.10 bits - 1024 gains).

3 ERRORS CORRECTION AND CALIBRATION

The AD fine converter should work with spare space from 15/16 to 16/16 range for AD 4 bit coarse converter. The VGA should have the value of each gain calibrated. The process of calibration should be automated. In fig.3 the system of calibration is presented. There are four components: calibrator, computer PC, EPROM simulator, FP converter .

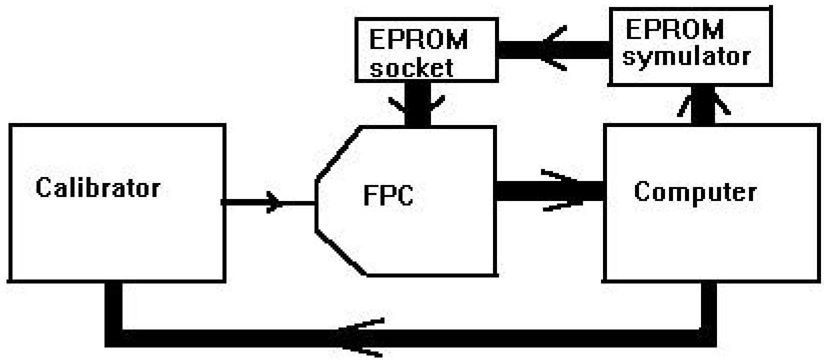

Figure 3. Calibration system

The flow-chart in fig.3 is marked. The computer set the value of calibrator output voltage. The calibrator sends the voltage to the FP converter input. Next, the system wait for the stable, digital signal of FPC, the computer reads this one and calculates the difference between stored value for calibrator and FPC output. Each difference above the final error (for e.g. $\delta < 0.1\%$) should be written to the EPROM or EEPROM simulator and checked again. The process of calibration must be repeated until the error of conversion reached the minimum.

The constant value of the gain difference should be set via EPROM simulator and stored afterward in the EPROM memory. The calibration system allows to adjust FP converters easily with many gains (practically up to 1024, 10 bits). There is software calibration proposed by Fluke [5], [6] or other companies. The problem lies in simulation and preparing the prototypes.

4 CONCLUSIONS

The inconvenience of FPC is limited frequency bandwich of VGA. The FP converter should operate up to kMHz , than the next step is replacement the standard VGA by distributed pre-processing circuit (DPC) with conversion rate as fine converter.

The ***new*** in this approach is the relative, measurement error stabilisation thanks to independent relative discretisation error. The new situation in Metrology is supposed as stable, relative conversion error in analog to digital conversion. It means that user of such instrument with FPC applied, should not have situations with a few digits on the display and high discretisation error. Other, positive feature is external simplicity of conversion and clear internal structure of FP converter. All blocks from fig.2 should be packed in one ASIC integrated circuit (one chip structure).

Float point arithmetic and error correction installed on the chip should cover the desired range of conversion. The range switches should disappear and result will be calculated correctly without zero reading in front of result digits. This solution should have different applications, however it was born during the work with project of electronic watt-hour meter. The simulation results however it was created during the work with electronic energy counter. The simulation results will be presented during conference.

It should be stressed that from the **user** point of view the difference between old and new method applied in multirange device is not as important as for the **producer** who wants to sell the best quality product. Even such small difference as 0.66% stable error in opposite 0.3% and more (Fig.1) for standard solution is important. What is more this solution can be developed without any permission.

REFERENCES

[1] E.A.Czudakow, The cars construction and calculations, 1951, p.95, Moscou .
[2] Roubik Gregorian, Gabor Temes, Analog MOS Integrated circuits for signal processing, A Willey , Interscience Publication.
[3] Design of analog integrated circuits and systems, Kenneth R. Laker, Willy M.C.Sansen.
[4] Reference Catalogue AD 1999
[5] Fluke, MET/CAL, Calibration Software, demo disc , 1989 John Fluke Mfg. Co., Inc.
[6] Fluke, MET/TRACK, Calibration Software, demo disc , 1989 John Fluke Mfg. Co., Inc.

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