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Energy Ventilation Air Flow Electronic Meter

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Abstract: ***The measurement of ventilation losses is one of several types in the energy balance of building, depends on nonlinear single slope type analog to digital convertor (NL-ADC), in this papera digital electronics method is described which is useful in measuring the ear flow via leakage per meter of length of windows and doors. The pressure difference signal is provided as an electrical voltage through appropriate transducer, the digital instrument receives the voltage and processes it together with input coming data of the living area geometry, the resulting readout is digital output number representing of the air flow in the building, the energy ventilation meter will be tested in two different room to measure energy conservation in building related to ventilation losses measurement.***

Keywords: ***(NL-ADC), measurement, papera digital electronics, measurement. Appropriate transducer***

I. INTRODUCTION

In the field of energy conservation in building, the measurement of ventilation losses is one of the several types in the energy balance of building, the other type are such thermal losses of walls and the thermal losses of windows. The method depends on on nonlinear single slope type analog to digital convertor (NL-ADC) , instead of one integer, the signal slop ADC employ three analog integrators. These integrators together with combination of a voltage – to frequency convertor (VFC) provide a digital count that represents the air flow in the building.

The design employs up to data electronic hard ware from the analog-switches, integrators, comparators… etc. to the digital counting, gating and control logic circuitries. These type of circuits provides flexibility of practical design assessing the energy demands of building and is quite useful for the mechanical engineers associated with demand and conservation of energy of buildings.

II. THEORY OF OPERATION

The electronic system is required to find the crack's air- flow using digital technique, the equation of crack's air- flow is:

$$\text{crack's air} - \text{flow} = a\,(\Delta P)^{2/3} \quad \text{.....} (1)$$

Where a is the living area geometry.

ΔP is The pressure difference signal.

The pressure difference signal ΔP is provided as an electrical voltage V_1 by means of appropriate transducer.

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This signal is applied simultaneously to VFC circuit and three cascaded integrators I_1, I_2, and I_3.

At $t = t_0$a reset pulse R as in figure (1) is applied to these integrator and the counter.

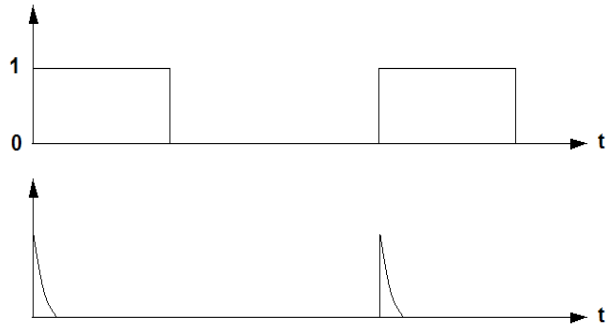

Figure 1: Reset Pulse.

The cascaded integrators arrangement will provide the following output voltages V_1, V_2, and V_3as in figure (2):

$$V_1 = -\frac{1}{RC}\int_0^t -V_0\,dt$$

$$V_1 = -\frac{V_1}{RC}\,t \quad \text{.....} (2)$$

$$V_2 = -\frac{1}{RC}\int_0^t -V_1\,dt$$

$$V_2 = -\frac{V_0}{2(RC)^2}\,t^2 \quad \text{.....} (3)$$

$$V_3 = -\frac{1}{RC}\int_0^t -V_2\,dt$$

$$V_3 = -\frac{V_0}{6(RC)^3}\,t^3 \quad \text{.....} (4)$$

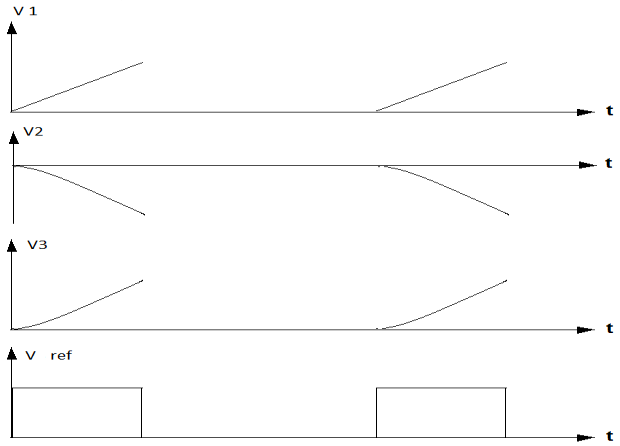

Figure 2: the output of cascaded integrators and reference voltage.

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The output of third integrator V_3 is compared to V ref to control the pulses of the VFC as in figure 3 to pass through gate (AND) to clock the main counter.

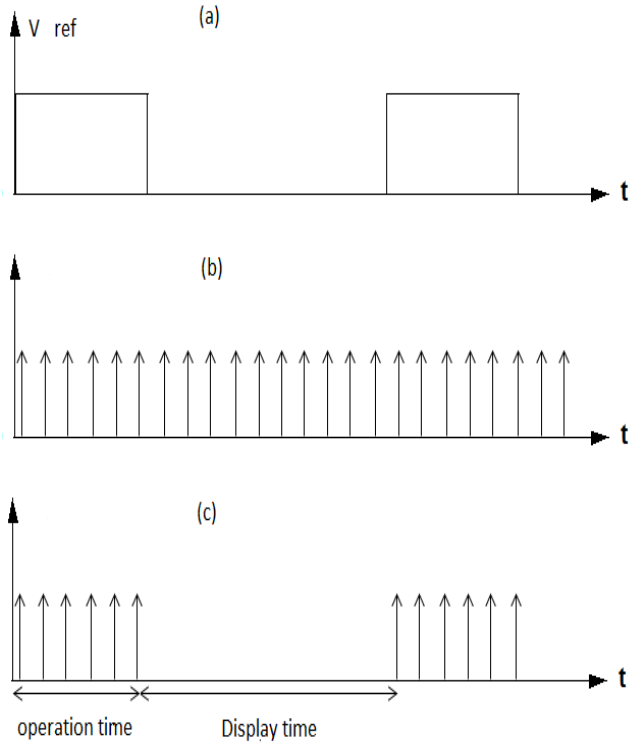

Figure 3: timing diagram (a) reference voltage (b) Pulses of VFC (c) clock of main counter.

At t=T

$$V_3 = V_{ref}$$

Therefore from eq. 4

$$\frac{V_1}{6(RC)^3} T^3 = V_{ref}$$

$$T = \sqrt[3]{6}\, RC \sqrt[3]{\frac{V_{ref}}{V_0}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

If the counter reaches N count during the period T by a clocking frequency of $1/\tau$:

$$\therefore N\,\tau = T \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

Therefor from eq (5) and (6):

$$T = \sqrt[3]{6}\; RC \left(\frac{1}{\tau}\right) \sqrt[3]{\frac{V_{ref}}{V_0}}$$

By making $1/\tau$ proportional to the voltage V_1 by means of suitable VFC circuit,

$$\frac{1}{\tau} = f = k_f V_0$$

Where K_f is the Hz/V conversion constant of the VFC.

Hence,

$$N = \sqrt[3]{6}\; RC \left(k_f V_1\right) \sqrt[3]{\frac{V_{ref}}{V_0}}$$

Or

$$N = \sqrt[3]{6}\; RC \sqrt[3]{\frac{V_{ref}}{V_1}} (V_0)^{2/3} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

Comparing eq (7) with general form equation (eq.1) of the system one can see that:

$$a = \sqrt[3]{6} K_f\, RC \sqrt[3]{V_{ref}}$$

And $\Delta P = V_0$

Hence the digital output number N is proportional to the crack air fallow required.

III. CIRCUIT DESCRIPTION AND RESULTS

The electronic circuit utilizes both analog and digital circuit sections employ three precision integrators, analog switches and comparator circuit (4151) and three BCD counters, circuit digram shown in figure (4). Figure (5) shows the calibration curve of the output digital number (N) against the applied voltage (V_0) where the collected data is drawn with matlab program. The accuracy of measurement shows a difference of around 2% between the actual and measurement calibration curves.

This is due to the offset errors of op-amps and VFC conversion nonlinearity together with analog switches S_1, S_2 and S_3 on resistances.

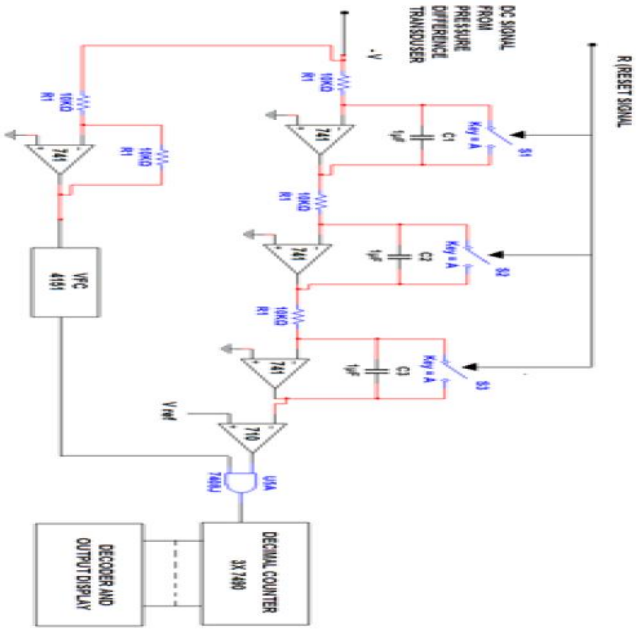

Figure (4) digital air flow velocity meter circuit diagram

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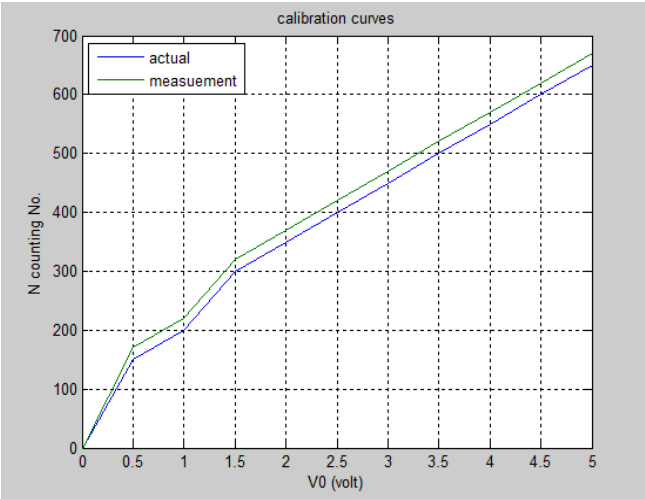

Figure 5 calibration curves.

As ventilation losses increased or decreased there will be changing in temperature, however. This meter have been tested in two different room laboratory and meeting room in hot weather, the meter measures the ventilation losses through the windows and doors as measure of temperature increased in rooms.

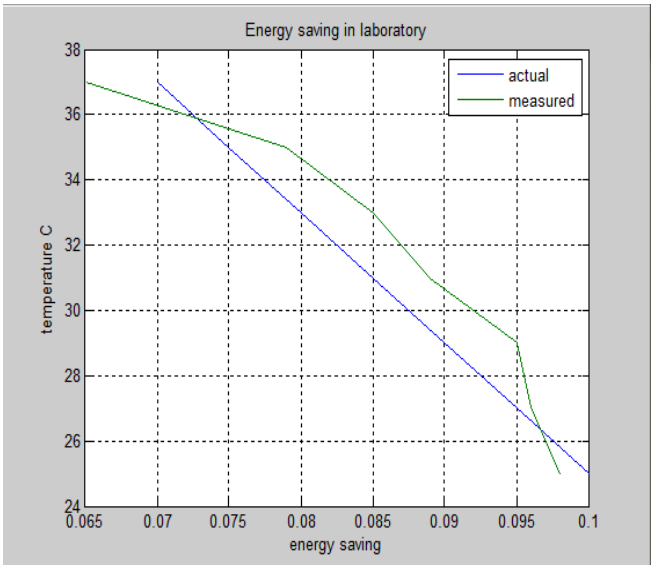

Figure (6): Energy saving of various temperatures for laboratory room

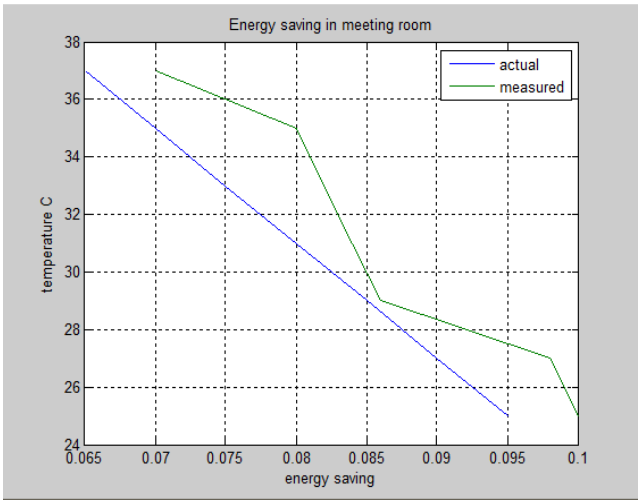

Figure (7): Energy saving of various temperatures for meeting room

IV. CONCLUSION

This paper described a digital meter useful in the measurement of air flow via leakage per meter of length of windows and doors. The error quoted is of the order of 2%. The meter has been tested in tow rooms and the results of measuring shows small percentage of error between actual and measured calculation of energy saving per temperature. The device is quit useful tool in the assessment of energy conservation in building related to ventilation losses measurement.

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