One of the Engineering Solutions of the Aircraft Fuel Gauge

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Abstract

Measuring of fuel quantity in the aircraft fuel tanks is concededly very important thing. In this paper, one of the modern conceptions of the fuel gauge of the aircraft is presented, involving digital signal processing, temperature error correction and fuel quantity data linearization.

Introduction

The data giving fuel quantity in the aircraft tanks belong surely to the important information which the aircrew needs for successful completion of flight. With a greater number of tanks, information is useful whether ever and how the fuel is being transferred from individual tanks into the so called consumer tank and from there to the aircraft engine(s).

The most used and probably also the most reliable method to measure the fuel in the recent aircraft is the measurement and evaluation of the capacity (the capacitance) of sensors of individual tanks. Current fuel gauges regularly need to be accommodated to concrete aircraft tanks, to be “hand tailored”. Thus for each type and variant of the aircraft a specific system of fuel measurement is being developed and manufactured which influences the price as well as the time necessary to design the system of a fuel gauge.

The modern conception of the fuel gauge of the aircraft – which is being developed in collaboration with the company MESIT přístroje s.r.o. Uherské Hradiště – removes this problem to a certain extent and enables in this way to react promptly on the client’s demands.

The basis of a modern conception of the fuel quantity measurement

The conception of a modern fuel gauge is based on another way of processing the capacity change then that one which was used in hitherto practice. The principle lays in transfer of the capacity change to the change of pulse width (in electronic circuits which are part of each sensor), subsequent “measurement” by means of pulses with directly defined width in a 16-bit scaler of a general microprocessor system, and figuring the “measured” values in the analogue and digital form.

The system of the modern fuel gauge can be divided into three functional electronic packs (Figure No. 1) which consist of:

- the pack of transducers consisting of proper capacity sensors and the capacity sensors electronics (CTEP),

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- the pack of electronics which contains microprocessor systems (μPS), a module of communication with the MFD (multifunctional display) with the transfer on the serial line RS-485, pump switches, signal switches of the fuel rest and a feed module,
- the indicator(s) with the electronics to control the stepping motor (SM), and the digital display (DSP).

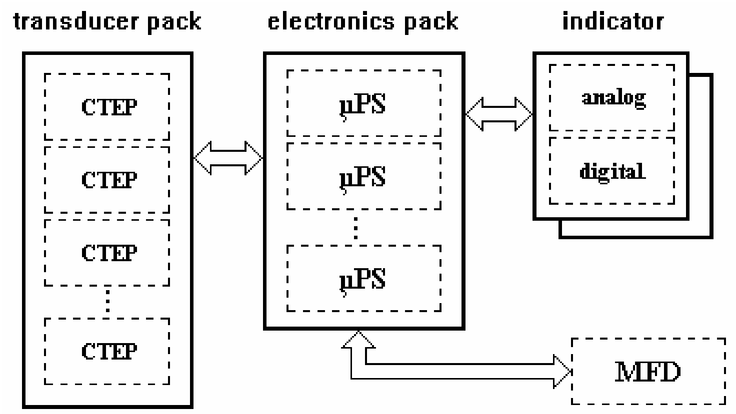

Figure No. 1: The block scheme of a modern fuel gauge

Each of the electronic packs represents an entirely independent constructional part and it can be manufactured and subsequently operated independently. The transfer of information to and from individual packs is implemented by means of the interface RS-422 with its own communication protocol.

The number of transducers is determined by the requirement of the number of measured aircraft tanks, possibly external tanks. The highest demands are being imposed on the construction of the CTEP electronics including the necessity of purposefulness also under condition of very low temperature -55°C without any loss of required measurement precision (approx. under 1%). The measurement precision of the transfer C/Δt determines the final precision of the fuel gauge.

The number of μPS in the pack of electronics is given predominantly by the number of outlet channels for the display(s). Each analogue indicator with the SM needs one independently working μPS, all digital indexes (including the communication with the MFD) can be linked to one μPS. By means of the parallel arrangement (back up), the inherent reliability of the pack of electronics can be improved.

The indicator contains only the electronics to control the SM and DSP, necessary feed resources, communication and illumination circuits of the indicator. The indicator can be designed in variant forms, with both outlets, with only the analogue or only the digital one; in simpler and cheaper variants of the fuel gauge, the pack of electronics can be placed into the case of the indicator.

Temperature compensation of the measurement and linearization of the indicator data

The measurement capacitors of the fuel gauge are usually designed as cylinders with coaxial electrodes. The fuel level in the tank, since also in the measurement capacitor, divides the cylinder in two parts with various dielectrics – the fuel and the air (saturated with fuel steams, possibly steams of other substances). The relative permittivity of the air in the tank differs only insignificantly from the permittivity of the vacuum and the influence of its temperature dependence on the result of the measurement can be omitted.

The temperature dependence of the fuel relative permittivity inconsiderable (e. g. SHELL company gives temperature dependence factor $\delta_\varepsilon = -1{,}7833 \cdot 10^{-3}\ {}^oC^{-1}$) and it can be expressed as:

$$\varepsilon_{rpal}(t) = \varepsilon_{rpal}(t_c) \cdot [1 + \delta_\varepsilon \cdot (t - t_c)] = \varepsilon_{rpal}(20) \cdot [1 - 1{,}7833 \cdot 10^{-3} \cdot (t - 20)],$$

where t_c is the calibration temperature - usually $20^o C$.

The best solution of thermal compensation is to put compensation capacitor into one of aircraft tanks so that the capacitor will be fully and always under the fuel level. We can compare “dry” and “wet” capacities and get possession of information for both, thermal fuel compensation and compensation of productive variations of fuel specific inductive capacity.

Another possibility is to know temperature dependence factor of the fuel and to measure fuel temperature, e.g. by means of temperature dependent resistor. Electronic circuit (the same as the CTEP) produces pulses with temperature dependent pulse width. This temperature signal is then used for fuel quantity temperature correction by means of electronics pack software. This must be low cost solution, but the productive variations of fuel specific inductive capacity is not solved and the accuracy is sure lower then former solution.

With respect to various fuel tank forms, the non-linear dependency of fuel elevation (measured transducer capacity) and tank fuel quantity is evident, but the linear scale of the fuel indicator is usually required. Linearization of the fuel gauge reading can be realized just in electronics pack – see Figure No. 2.

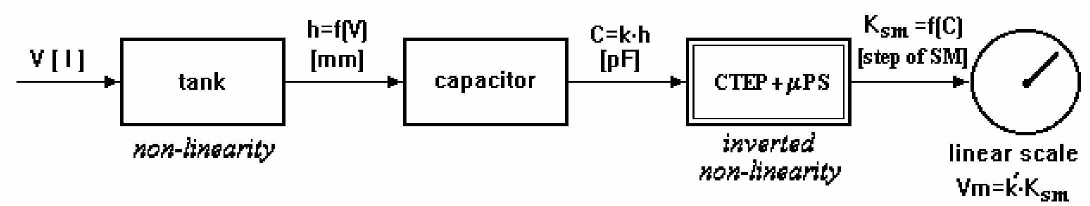

Figure No. 2. Signal chain of capacitive fuel gauge

Rectangular pulse (as a response to μPS request) is created in capacitive transducer electronic pack (CTEP). The pulse width (proportional to transducer actual capacitance) is measured and processed in μPS so that width is reduced according to offset capacitance (given transducer “dry” capacitance and a supply lead capacitance). Stepper motor steps number of the indicator pointer is then assigned in line with resulting pulse width by means of linearization function, which is built-up from set of linear functions. Dial pointer deflection over the linear instrument dial is the end of signal chain. The principle of linearization in graphic-analytic representation is demonstrated in the Figure No. 3.

In the first quadrant the given dependence of fuel level and its mass quantity in the tank is shown. In the second quadrant transducer characteristic, consequently given dependence of its capacitance and fuel level in the tank is plotted.

In the forth quadrant required combined characteristics – dependence of output reading and fuel mass quantity in the tank is presented. By connections between corresponding points of single characteristics we acquire expected relation of linearization, which have to be (as software) inserted into the fuel gauge microprocessor system memory.

With respect to possibilities of the fuel gauge microprocessor system and the memory store size, the implementation of linearization function based on the set of lines looks to be optimal, simplest and cheapest problem solution.

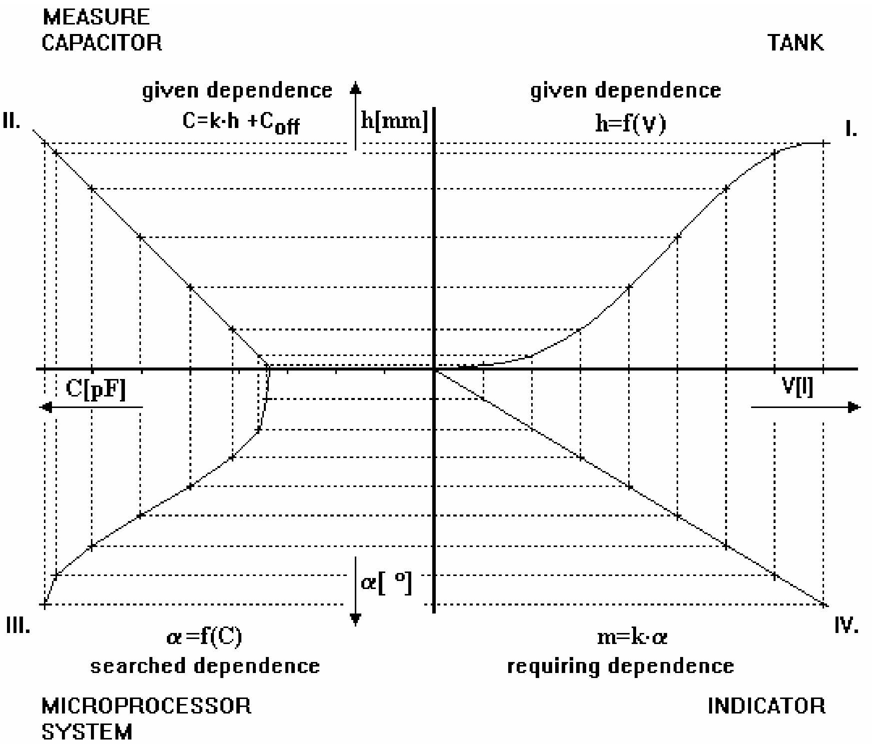

Figure No. 3. Linearization of volume characteristic of a tank

These lines slopes must be chosen optimally on account of minimum variance of approximation. To the effect the method of least squares in the form of purpose-created computer software was used.

Fuel mass quantity data (as pilot preferred - of either each tank separately or all tanks summarily) is via fuel indicator displayed for pilot or sent to MFD, perhaps even to flight data recorder. This modern approach to fuel gauge construction is conductive to built-in-test-equipment implementation, which means that it is possible to check state and operation of fuel gauge set on line and to inform pilot or operator about it (fault signature is displayed).

Conclusion

New system conception, i. e. digital processing and software linearization of transducer signals, simplifies design, manufacturing, testing and assembly of fuel gauge sets. Transducers may not be adapted to volume form of tanks, the user (according to design of product possibilities) only chooses the type and number of transducers, its proportions and mounting in tanks. In the following the user can select indicator size and indication method, measuring range and illumination device, eventually other special requirements. Nowadays, this conception fuel gauge is produced by MESIT přístroje s.r.o. Uherské Hradiště, and successfully run into L-159 B ALCA aircrafts.

Literature

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