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DEVELOPMENT OF A DATA ACQUISITION SYSTEM FOR LIGHT AIRPLANES FLIGHT TESTS

Frederico Mol Alvares da Silva
Federal University of Minas Gerais (UFMG) – Centre for Aeronautical Studies (CEA)
fredmol@task.com.br

Paulo Henriques Iscold Andrade de Oliveira
Federal University of Minas Gerais (UFMG) – Centre for Aeronautical Studies (CEA)
iscold@ufmg.br

Abstract. *Flight tests are important mainly in the development phase, providing data to model validation and to check some premisses that have been made in previous phases. These tasks are useful to generate true data to the homologation office as well. To develop a system for light airplanes the Centre for Aeronautical Studies of the Federal University of Minas Gerais designed a data acquisition system using PIC microcontrollers and Palmtops (PDA). In this paper the main considerations for the specification of this system, and some functional algorithms and applications in the mobility field are shown. An portable GPS was included to provide additional data to the system, and some considerations about this integration were made as well. Considerations about tests in automotive and aeronautical fields were made.*

Keywords*: Flight Test, Data Acquisition System, Light Airplanes*

1. Introduction

In the last decades the use of flight tests in the aeronautical industries have been increased, mainly because the parameters identification technics have been used in the flight mechanics field, including control systems and flight simulation as well.

In the light airplane industries the flight tests are useful to develop new solutions and technologies. The work made by Johnson (2005) is an example of how the light airplane tests can improve the future developments. Outside of the industry, in the academic field, the experimentation are essential to add pratical and realistic experience to the students, helping the industry future development, since the engineers will be more prepared to the work. Universities of all the world are including flight tests in the scope of the engineering course. The Technical Universities of Germany and the master course of the Cranfield University, in the United Kingdom, are examples of how the flight tests can be applied in the academic field.

Recently some Universities have been using light airplanes and UAVs in flight tests, providing data to the research, development and didatic issues. The work made by Dr. Domenico Coiro from the University of Nápoli, Italy, shows that the utilization of light airplanes for this purpose is promissing, because the data acquisition, maintenance and operational costs are low (Coiro, 2002).

To provide a data acquisition system that can be used in the airplanes developed in the CEA – UFMG, the system was developed. This data acquisition system is applicable to the new scope of the Aeronautical Engineering Course, that includes a flight test discipline, and to others research and development tasks as well. The requirements and constraints of the system were made based on the airplanes or vehicles involved, cost, maintenance and portability.

In this paper the development of the data acquisition electronic unit and the integration of the peripherics are explained. In future papers the sensors development for flight data acquisition will be presented.

2. Requirements of a Light Airplane Data Acquisition System

Some specific requirements applied to light airplanes must be considered. The main requirements applied to this system are (Iscold et all, 2004):

- Portability – light airplanes have a limited space and payload weight
- Operation – the operation of the system must be automatic, because light airplanes are mainly monoplaces or biplaces
- Cost – light airplanes production are limited to a few number or units, so, to avoid an increase in the product price the system must be cheap
- Adaptability – the diversity of flight tests that can be made in a light airplane, involving different areas (aerodynamics, flight mechanics, performance etc.), requires that with just a few modifications in the sensors, and no modifications in the general architecture of the system, a large number of tests can be made

Based on the requirements described above, the basic architecture for the system was made, figure 1.

Figure 1 – Basic configuration adopted.

Some advantages of this basic configuration related with the system requirements are:

- Microcontroller utilization – provides reduced cost with some built-in capabilities: A/D converter, serial comunication, high speed;
- Serial communication – provides an easy and flexible way to connect a lot of computer or data storage devices: PCs, PDAs, scientific calculators, wireless modems for telemetry, data links;
- Computer device – provide permanent memory storage for acquired data, control of the data acquisiton board, and must satisfy the portability requirements as well;

Based on the assumptions above, the system obtained will be adequate for light airplanes and for the specified requirements.

3. Microcontrollers

Microcontrollers are a new concept of integrated circuits based on a multifunctional architecture (Zelenovski, 2003). The majority of microprocessors requires a lot of discrete components and CI´s to execute a relative simple function, resulting in large and complex hardware. This is based on a fact that the microprocessors must be flexible, in the application point of view. This architecture is often dificult to update, and requires a lot of electronics knowledge and low level programming.

Incorporating some basic functions inside of a microcontroller, the hardware can be quite simple and with low cost as well. Some of these basic functions are: A/D converter, comparator, PWM, serial communication, internal clock, RAM/EPROM memory, flash memory and programable I/O. Some microcontrollers incorporate all of these functions in a single chip, the additional discrete components are minimal (Zelenovski, 2003).

Another advantage of the recent microcontrollers is the programing process and the language used (Zelenovski, 2003). The software can be made with high level languages, C++, Basic, or low level language (assembler). To upload the software into the microcontroller, just a PC and an external board is required.

3.1. PIC Microcontrollers

Actualy, a large number of different microcontrollers are available for different applications and from different manufacturers: Zilog, National, Motorola and Microchip. The Microchip developed the PIC microcontroller family, very popular nowadays.

PIC microcontrollers uses the RISC (reduced instruction set computer) technology, that comprises a reduced set of simple instructions (Microchip, 2005). The main advantage of this technology is based in the fact that simple instructions are processed faster than complex instructions.

The PIC family are divided in three distinct types (Microchip, 2005), with different characteristics, table 1.

Table 1 – PIC family subdivision.

Type	**Instructions**	**Bits[(1)]**	**MIPS[(2)]**	**Pins**
High Performance	79	16	10	18-80
Mid Range	35	14	5	8-64
Baseline	33	12	5	6-40

(1) Bits – Número de bits do microprocessador.

(2) MIPS – Millions of instructions per second.

One of the advantages of PIC family adoption refers to the system adaptability requirements. With the RISC technology the system changes required for a expansion or adaptation are quite simple.

Another important aspect is the memory used by the microcontroller. The PIC family are available in three types of internal memory: OTP, FLASH and ROM. During the development phase the utilization of FLASH memory is essential, because this memory have the capability of re-program the firmware almost indefinitely. Therefore the cost related with the development or expansion of the system is reduced.

For data communication, the PIC support the following technologies: USART, I^{2}C, USB, SPI e CAN. Actualy, the communication standard more often used is the USART, but gradually the USB have been used instead of USART.

3.2. Microcontroller Model Selection

To choose a more apropriated model for this application, all the devices comprised in the Mid-Range with the internal A/D converter were evaluated. Only the devices with FLASH memory were considerated, preserving the adaptability requirements.

Finally the PIC16F877A microcontroller was choosen for the system, based on the following assumptions:

- Easy to buy in the local market;
- Cheap firmware recorder device;
- Bibliography available (Microchip, 2005).

The microcontroller technical specs is shown in table 2.

Tabela 2 – Microcontroller technical specifications (Microchip, 2005).

Model	Memory (bytes)			I/O Pins	A/D	Serial I/O	Max. Clock
	FLASH	EEPROM	RAM				
PIC16F877A	14336	256	368	33	8x10bit	AUSART,MI^{2}C/SPI	20MHz

4. The Data Acquisition System

The first tests were made using an HP48G scientific calculator as a computer device, to control the data acquisition and for data storage. The block diagram of the system is shown in figure 2. The lower processing speed and memory capacity of the HP48G are limitating factors for data acquisition, however, the use of the HP48G was essential in the PIC firmware development phase. The use of this calculator for flight tests is justifiable only for didactical application, that requires low acquisition data rate.

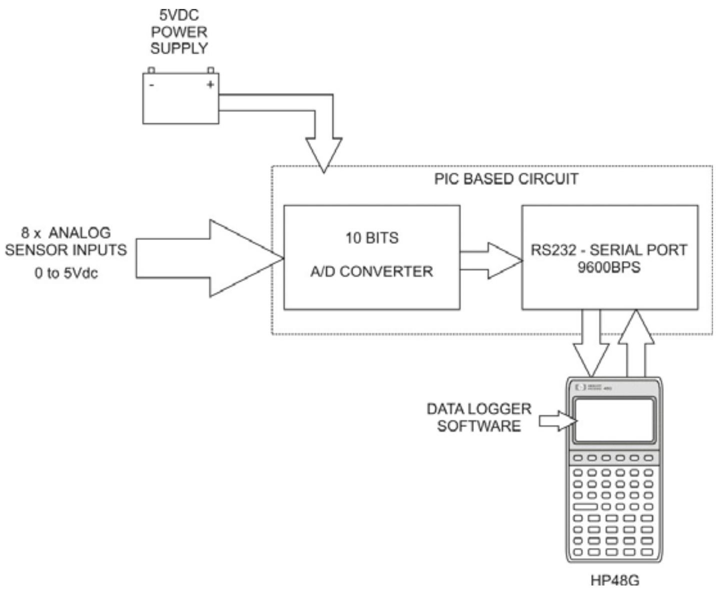

Figure 2 – Data acquisition system using an scientific calculator.

For the flight tests an GPS system is essential to provide data of ground speed, heading and position of the airplane. In order to include GPS data into the data acquisition system serial communication was used. The majority of the portable GPS units have the built-in serial port and uses the NMEA0183 protocol, so, no specific GPS unit is required.

In the development phase an GPS Garmin model GPSIII was used. The GPS send data through serial port at each 2 seconds (0.5Hz) at a baud rate of 4800bps. The GPS was used to syncronize the data acquisition system, when the GPS data is received by the PIC board, the analog data in the sensor inputs are read. Afterwards, the data is sent to the computer device. The gap between each GPS data (less than 2 sec.) is used by the PIC to acquire and send the analog inputs to the computer device, this gap is a limitating factor for the data acquisition rate.

The data transmission for the computer device is made by serial communication. The computer device must comply with the requirements and constraints established for the data acquisition system, mainly portability, performance and cost requirements.

For the computer device a PDA manufactured by PalmOne was used. The advantages of this device are: portability, color display, efficient and stable operational system (PalmOS), and large memory capacity. The block diagram is shown in figure 3.

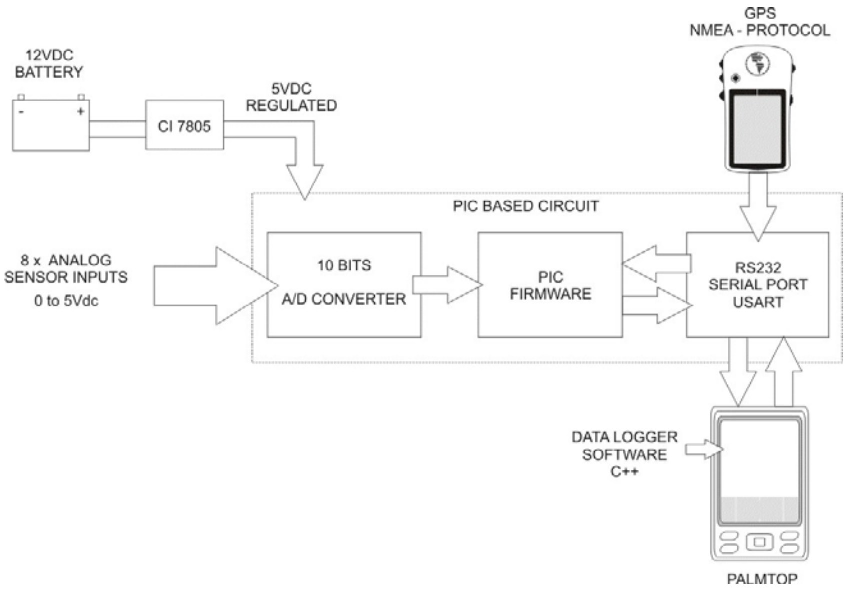

Figure 3 – Functional block diagram.

To increase the number of analog input channels to 32 multiplexers were used succesfuly, maintaining the data acquisition rate acceptable for flight tests.

5. The Microcontroller Firmware

The development and design of the firmware is the key of the system. The firmware programming must be made to maximize the processing speed, maintaining the desired data acquisition rate. To achieve the maximum processing speed the firmware was designed using an assembler algorithm.

In figure 4 the fluxogram of the firmware without GPS capability is shown.

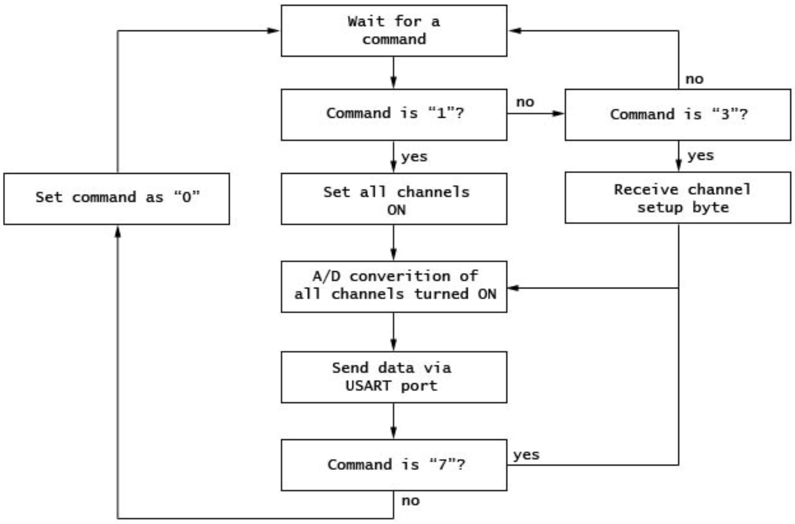

Figure 4 – PIC firmware flowchart – without GPS.

In this case, the communication between the computacional device and the microcontroller is bidirectional, and the control and synchronization of the acquisition is made by the computacional device. To synchronize three basic commands are used:

- 1 (00000001) – send just once the data of the 8 input analog channels;
- 3 (00000011) – send just once the data of all ON channels, based on the second byte sent after this one (1 – ligado, 0 – desligado);
- 7 (00000111) – send continuously all ON channels, based on the second byte sent after this one (1 – ligado, 0 – desligado);

Using this procedure, the data acquisition rate is controled by the computational device. If a Personal Computer is used as a computational device, data acquisition rate of up to 6kHz can be achieved, using the “7” synchronization command.

6. Adding GPS Data

With GPS the acquisition synchronization device is the GPS instead of the computational device, therefore, the microcontroller firmware with GPS is different from the system without GPS. Initially, at the beginning of the development, the data acquisition rate was defined at 10Hz, and since the GPS data sent frequency is 0.5Hz, the analog channels have to be read and sent 20 times for each GPS data packet. Actually, the GPS data sent frequency is 5Hz and the data acquisition rate is 30Hz. At each GPS data read the channels must be read six times. This synchronization is essential to avoid data loss and firmware locking. Therefore, the firmware must be reliable and stable.

One important task of the firmware is the NMEA0183 protocol decoding (NMEA, 2005). The firmware must locate a string “GPGAA” in the GPS data packet and detach the necessary information. The algorithm developed to do that have a fixed number of instructions, avoiding synchronization problems.

The fluxogram for the firmware with GPS at 0.5Hz and data acquisition rate at 10Hz is shown in figure 5. Must be noted in figure 5 that a flag containing “**” is sent always before the GPS decoded data is sent. This flag is used to indicate the initial part of the data sequence. In the case of GPS data lost, the information acquired by the analog ports can be identified.

8. Comparison With Anothers Systems

Another data acquisition systems for light airplanes have been developed as well. Three systems with the same main characteristics were compared in this section.

- ICASIM System – developed by the Swiss company SIMTEC (SIMTEC, 2005);
- PODS System – developed by the English company Flight Dynamics (PODS, 2005);
- DPA System – developed by Prof. Domenico Coiro from the University of Naples, Italy (Coiro, 2002).

A comparison between the systems listed above with the CEA/FDAS system is shown in table 3.

Table 3 – Comparison between some flight data acquisition systems.

	GPS	**Inertial platform**	**Analog Channels**	**Nominal Sample rate**	**Maximum Sample rate**	**On-line Serial output**	**Storage device**	**Preço FOB**
ICASIM	yes	yes/outside	4	10Hz	na	no	Int. Drive	38kUS$
PODS	yes	inside	33	25Hz	1kHz	yes	PDA	20kUS$
DPA	yes	yes/outside	32	10Hz	na	no	Flash Card	28kUS$
CEA/FDAS	yes	yes/outside	32	30Hz	6kHz	yes	PDA	na

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The performance of the four systems is very similar, and in some itens the system developed in this paper (CEA/FDAS) is better. Only the DPA and CEA/FDAS have an open code, providing a way to improve the system and to add new sensors as well.

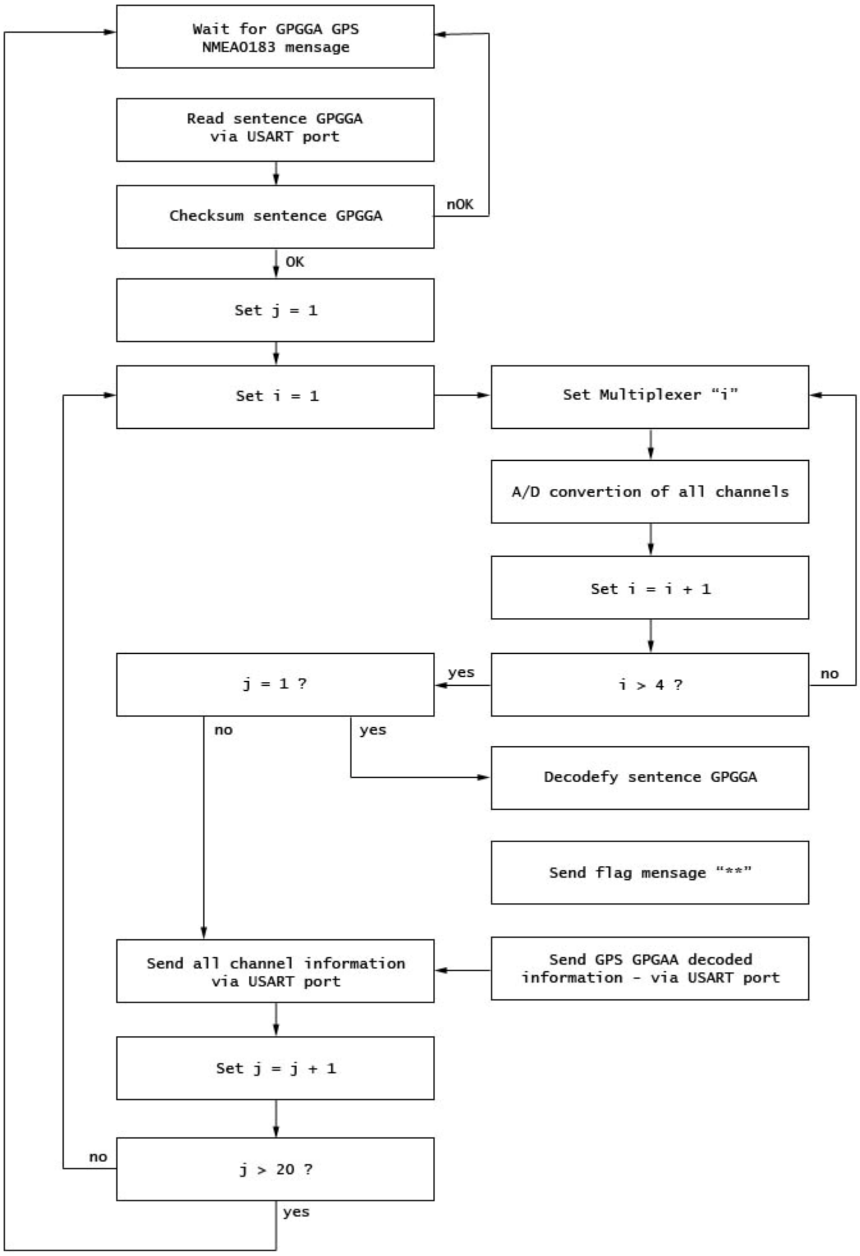

Figure 5 – PIC firmware flowchart – with GPS.

9. Applications

The CEA/FDAS system have been used extensively for light airplane flight tests in the Centre for Aeronautical Studies (CEA) of UFMG. Until the publication of this paper, three tests campaign were made succesfuly with this system. These tests involved three airplanes (figure 6), a training sailplane SZD 50-3 Puchacz, a very light airplane designed and built at CEA CB-9 Curumim and an UAV for the SAE AeroDesign competition.

Two applications related with others areas of science have been performed with this system: i) automotive dynamic tests data acquisition; ii) physiotherapy muscle force measurement. The applications listed above shows the versatility and adaptability of this system.

Figure 6 – Flight tests were made in three light airplanes with CEA/FDAS.

10. Conclusions

The PIC microcontroller used was considerated useful for the data acquisition application. The control and storage of the acquired data can be performed by a lot of devices with serial RS232 port, but the processing speed of the computational device must be evaluated for each application. A PC can be used succesfuly for applications where portability is not a requirement.

The use of HP48G scientific calculator was considered acceptable for applications that requires low data sample rate and low data storage.

For light airplane flight tests at CEA the use of PDA as a computational device was largely and succesfuly used. This device provides excellent portability and cost benefit ratio as well. The PDA was considered the best choice for light airplanes flight tests.

The use of open architecture (open code) that was used in this system provide an easy solution to upgrade the system for better performance and to add new capabilities as well.

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12. Responsibility notice

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