UT-VIV/AM-AIA

Task Title: TECHNOLOGIES FOR VACUUM AND TEMPERATURE CONDITIONS FOR REMOTE HANDLING SYSTEMS ARTICULATED INSPECTION ARM (AIA)

INTRODUCTION

This project takes place in the future generic plants (like ITER), Underlying Technologies (UT) in Remote Handling (RH) activities. The aim of the R&D program is to demonstrate the feasibility of close inspection of the Divertor cassettes and the Vacuum Vessel first wall. We assumed that a long reach and limited payload carrier penetrates the first wall using the 6 penetrations evenly distributed around the machine and foreseen for the In-Vessel Viewing System (IVVS).

The need to access closer than the IVVS to the Vacuum Vessel first wall and the Divertor cassettes had been identified. This is required when considering inspection with other processes as camera or leak detection.

The work performed under the EFDA-CSU Workprogramme includes the design, manufacture and testing of an articulated device demonstrator called Articulated Inspection Arm (AIA).

The AIA has to fulfil the following specifications:

- Elevation: + - 45 ° range,
- Rotation: + - 90 ° range,
- Robot total length: 7.4 meters,
- Admissible payload: 10 Kg,
- Temperature: 200 °C during baking – 120 °C under working,
- Pressure: 9.7 10^{-6} Pa – Ultra high vacuum.

The manufacture and procurement activities of the AIA robot are performed in the TW5-TVR-AIA Task.

2005 ACTIVITIES

PROTOTYPE MODULE ACTIVITIES SUMMARY

A vacuum and temperature module demonstrator was tested in a representative module of CEA-Cadarache mock up called ME60, under realistic operating conditions. Promising results were obtained in term of structural resistance of the system. The past year was dedicated to cycling test campaign to validate all the robot components.

TESTS CAMPAIGN

Cycling test campaign was carried on with the upgraded module manufactured in 2005 in task TW5-TVR-AIA. It enables to evaluate performances of the AIA system and to identify the weakest components.

Cycle is composed of elevation and rotation combinations:

Table 1: Cycle test description

Points	Elevation (°)	Rotation (°)	Waiting time (s)
1	0	34	60
2	17	0	60
3	0	-34	60
4	-12	-40	60
5	0	-34	60
6	28	0	60

More than 600 cycles were completed with a complete AIA representative payload.

Constraints computations introduced a safety factor: payload*1.2. Additional static tests enabled to verify this hypothesis.

Figure 1: AIA module during nominal load tests

Baking tests were also performed on the electronic components. A heating insulation and cables were added to the module to cope with the AIA nominal functioning conditions.

The tests performed with the upgraded prototype module have shown the benefits of the improvements, good performances of the new rotation actuator and generally a better behaviour of the module.

Some endurance tests under temperature have still to be done in Cadarache facilities and are planned in early 2006.

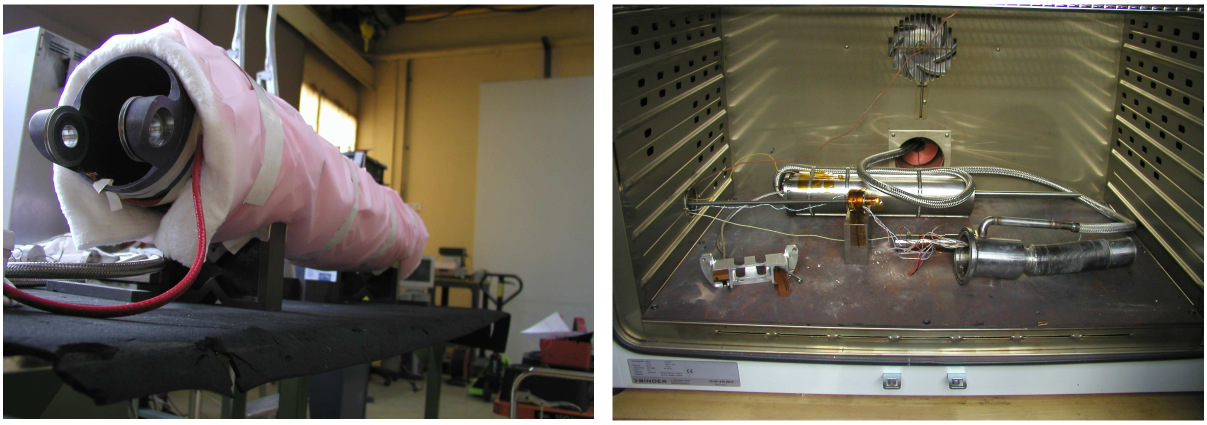

Figure 2: Heating insulation system and Baking tests

CONCLUSIONS

Demonstration of the AIA intervention feasibility in real temperature and vacuum Tokamak environment is planned on Tore Supra for the next years. The integration of the whole robot on Tore Supra is foreseen for 2007.

REFERENCES

European Fusion Technology Programme
- Task TW0-DTP/01.2, Task TW0-DTP/01.4, Task TW1-TVA/IVP, Task TW2-TVA/IVP, Task TW3-TVR/IVV, Task TW4-TVR/AIA. Task TW5-TVR/AIA

European Fusion Technology Programme
- UT VIV/AM-AIA, May 2005.

REPORTS AND PUBLICATIONS

CEA/DTSI/SCRI/LPR/05RT.098-Issue 0 Articulated Inspection Arm, Prototype module test report. D. KELLER / V. BRUNO.

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UT-VIV/AM-ECIr

Task Title: RADIATION EFFECTS ON ELECTRONIC COMPONENTS

INTRODUCTION

The well-known method commonly named “carrier current principle”, often implemented on consumer applications (home control instrumentation using electrical nets, data transfer using phone nets) has also proven its capacity for data exchange in severe environments and wires number limitation protocols.

Works done during years 2004 and 2005 focus on the availability to apply these realizations to a more complex situation such as remote control of maintenance tools of ITER and high level of temperature and radiation.

The mock-up was presented on the last 2004 report [1] while this document describes the validation of the prototype built under mock-up requirements. An embedded floating ground supply was integrated in the prototype.

2005 ACTIVITIES

Brief review of the engaged developments

The development of a full carrier current link with both data and supply, available under high temperature and dose environments, were previously initiated for the command of an embedded camera, using FSK protocols associated with PWM modulation to transfer data.
Some of the results coming from fusion tasks [2] [3] were also used to realise a mock-up to transfer low time evolution as those given by LVDT sensors.
Even if limitations were introduced by some components (mainly operational amplifiers used for 2nd order pass band adaptation), reasonable FSK frequencies signals of 250 kHz (logic “1” level) and 125 kHz (logic “0” level) were initiated on the mock-up. The full FSK signals is shown on figure 1.

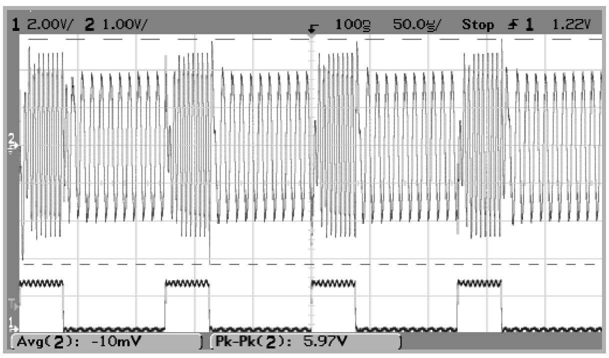

Figure 1: FSK modulation and data signals

An embedded floating ground supply was added to the mock-up and coupled to the FSK modulated signals in order to limit links between sensors and control room to a single wire. The bloc-diagram schema of figure 2 shows the main principles of the full experimental board.

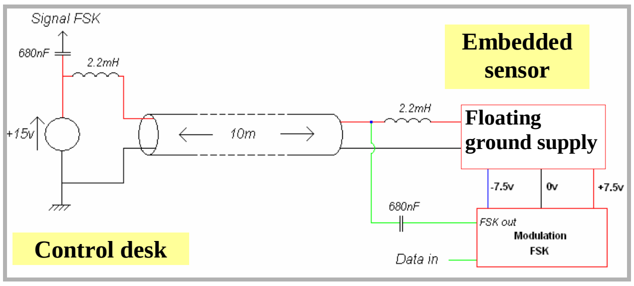

Figure 2: Floating ground and carrier current association

A ten meters 15 V supply line drives both supply and data, with appropriate filter cells on each side to separate the signals.

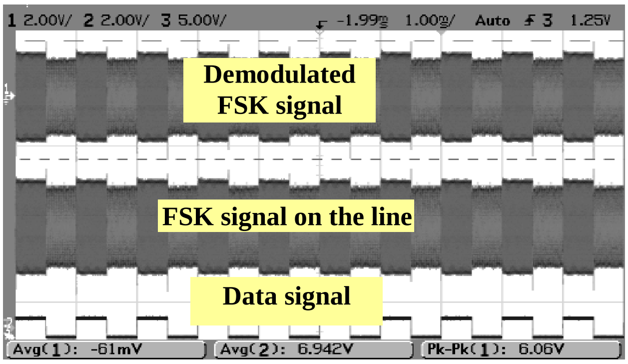

Figure 3: Chronograms of FSK signals

As shown on the chronograms of figure 3, the data clock signal was modulated with FSK protocols and added to the supply line. The demodulation chronogram does not showr significant degradations.

The final modulation of high level clock signal to convert logic “0” and “1” data signals allows a very simple and useful way to mix clock and data digital signals and, one more time, to avoid any need of additional clock wire (see the resulting chronograms on figure 4).

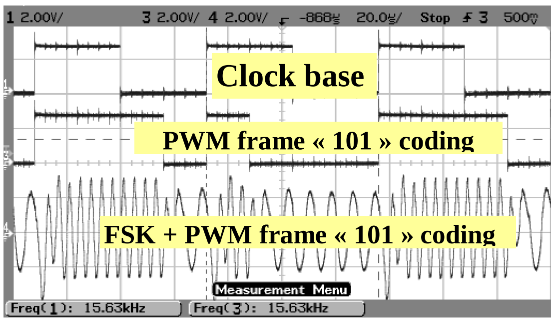

Figure 4: PWM and FSK modulation

Temperature validation

The full mock-up was submitted to thermal tests up to 150°C during long term periods with short stresses. On-line controls on main signals and supply values did not reveal major incidents or failures. Current delivered by the 15V external supply (16.9 V to take into account lost induced by the 10 meters cable) did not exceed 34mA independently of temperature level.

Internal floating supplies were stabilised to +7.5 V and -7.5 V which was a good result.

The three steps of the demodulation process controlled during thermal tests and represented on figure 5shown that modulation protocol kept its integrity. Demodulation was completed without lost of converted bits “101”.

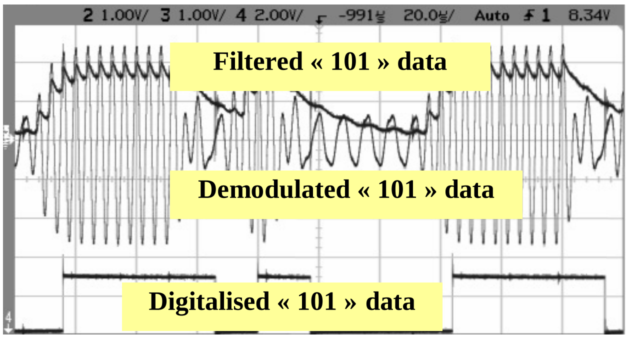

Figure 5: Demodulation process during thermal tests

Delay between emitted and received signals as reported on figure 6 was mainly introduced by line or filtered cells and triggered logic components. It should be possible to optimize the demodulation. But, in any case, because clock was carried out by data signals, this delay did not affect frame interpretation.

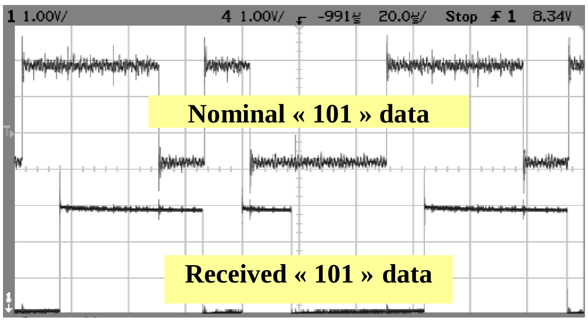

Figure 6: Full carrier current data link transmission

Prototype manufacturing

To avoid any side effects of radiation, a printed prototype was defined and realised in early 2005, based on the modules previously validated.

The prototype shown on figure 8 was then verified to room conditions. Data signal was simplified and identified to the clock signal at 3.9 kHz and the chronograms of the different signals were reported on figure 7.

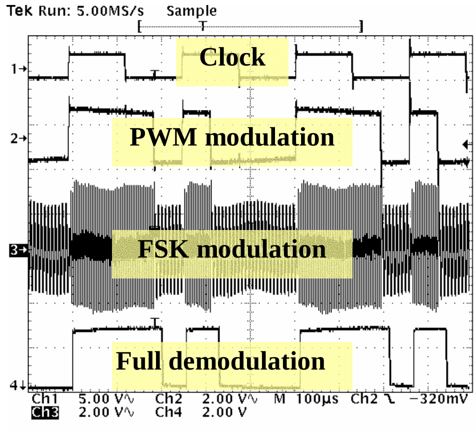

Figure 7: Room conditions measures

The full mock-up was validated up to 150°C with on-line control during long term periods and short stresses without any major incidents or failures. The signals showed a regular stability as can be seen on figure 6.

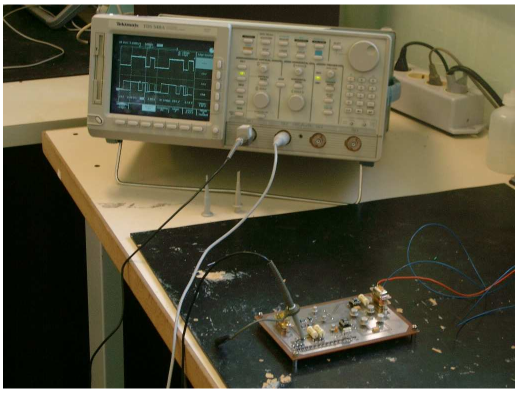

Figure 8: Prototype of a full carrier current link

Irradiation experiment

The irradiation took place from june 13th to july 28th 2005. Dose rate was about 5 kGy/h.
A test bed was realised. Some wires are added to report internal signal drifts. But, only one of them is needed for supply and data, a second is used for extern ground line.

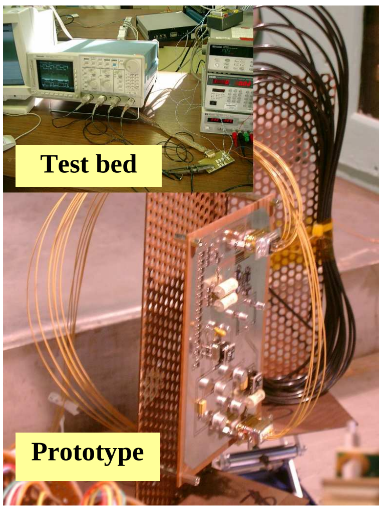

Figure 9: Prototype during irradiation process

Up to less than 2 MGy, no drifts occur on floating supplies measures. As shown on figure 10, external Vsupply and Vcc which is really applied to the prototype (after the 10 meters cable) have a very limited decrease often observed after significant total dose integration. Floating ground Vpol and Vnum used to supply logic components seem stable. External current delivered to the prototype start at 20 mA to finish at 10 mA with precision limited by the internal measurement of the supply.

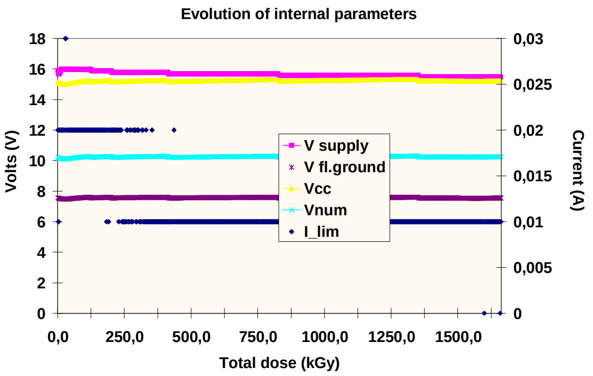

Figure 10: Evolution of internal parameters up to 2 MGy

Nevertheless, it clearly appears that chronograms of figure 11 give enough information to confirm that OPA affected to FSK 250 kHz line did not support such level of radiation, even with those with larger bandwidth.

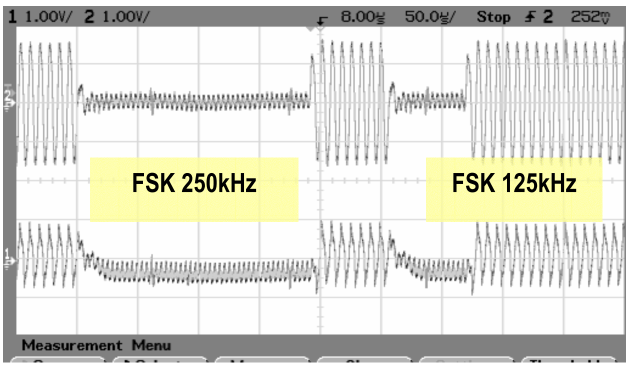

Figure 11: Lost of one of the FSK signals

A quick change of default components was enough to recover all the functionality.

The chronogram of figure 12 represented the full behaviour of the experiment. The continuous drifts on OPA characteristics affect at about 2 MGy the working state of floating ground and logic supply mechanisms. The recovery at about 2.5 MGy after withdraw and change of faulty components lets the experiment run up to 4 MGy, end of the irradiation campaign.

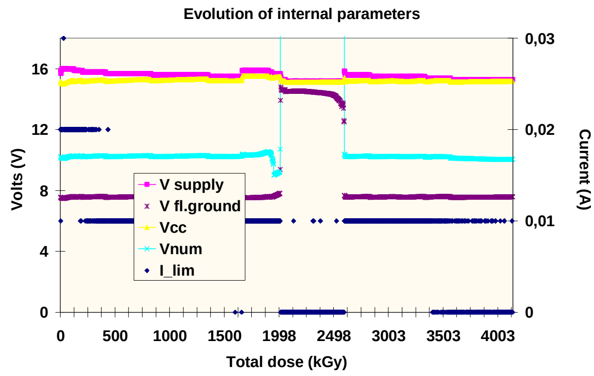

Figure 12: Full behaviour under radiation of intern parameters

Once again, at about 3 MGy, the drifts on OPA used for FSK modulations lead the experiment to unexploitable modulation signals (see chrnograms on figure 13). In order to avoid a new shut down of Gamma sources, no change was done.

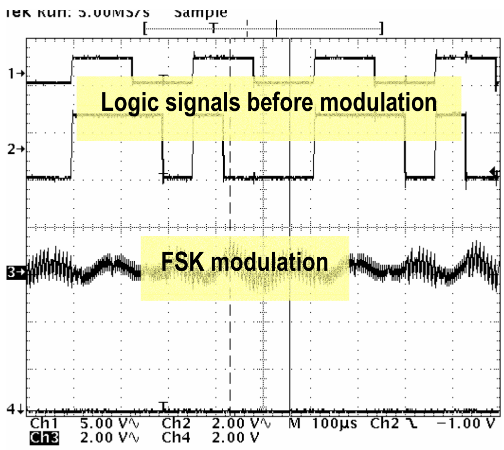

Figure 13: Lost of full FSK signals

The last recording chronogram of figure 14 confirms the complete lost of modulation while all the logic mechanisms necessary to create digital signals to be modulated leave in operational state.

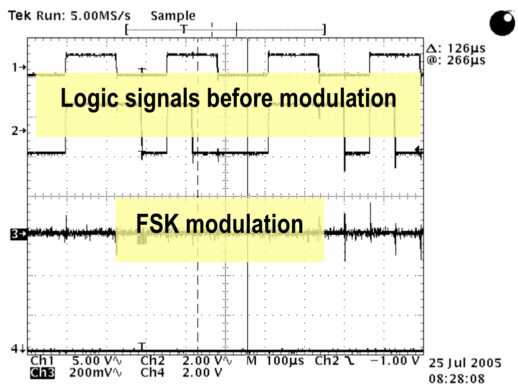

Figure 14: Logic signals at end of irradiation campaign

CONCLUSIONS

The volontaire approach to integrate a very common transmission protocol as PWM signals and FSK modulation on a single supply cable gives real opportunity for high temperature and high dose rate irradiation. The 2 MGy-2,5 MGy step seems to be difficult to manage because at that level OPA components have reached their extreme characteristics. Some of them were resolved by use of pseudo-darlington transistors in order to limit effect of load (as rules induced by previous experiments in the case of TW3/4/5-TVR-RADTOL tasks). Others have to be investigated.

In any case, as results of underline technologies, these useful prototypes could be a significant start for other carrier current applications in civilian nuclear activities.

REPORTS AND PUBLICATIONS

[1] Annual Report of the Association Euratom-CEA 2004.

[2] Annual Report of the Association Euratom-CEA 2003 (p 113-117).

[3] Annual Report of the Association Euratom-CEA 2002.

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UT-VIV/AM-Hydro

Task Title: TECHNOLOGIES AND CONTROL FOR REMOTE HANDLING SYSTEMS

INTRODUCTION

CEA in collaboration with CYBERNETIX and IFREMER has developed the advanced hydraulic robot MAESTRO. Control laws developed in the TAO 2000 controller made possible the use of the MAESTRO in a force reflective master-slave configuration.
Development around the actuating technology of the MAESTRO's hydraulic arm successfully proved on servo-valves prototypes the interest to use pressure control servo-valve instead of flow control servo-valve. The control is directly made on the pressure, i.e. the force which makes real improvement during force control modes which are extensively used in remote handling techniques.
In-LHC (French servo-valve manufacturer), developed a pressure servo-valve prototype that fits the MAESTRO's space constraints.
Operating in a fusion reactor requires a cleanliness level that oil hydraulic cannot ensure. Pure water hydraulics therefore proposes a good alternative and developments are today focusing in that direction. Feasibility of a pressure control valve running with water was proven and two prototypes were manufactured. Preliminary performance analysis was started to characterize the servovalve.

2005 ACTIVITIES

SERVOVALVE'S SPECIFICATIONS

Two prototypes were manufactured during year 2005. Design assumptions were defined to reach the following requirements:

- Operating pressure 210 bar
- Minimum flow rate 6 liters/min
- Bandwidth > 20 Hz on half the volume of an "elbow axis" Maestro vane actuator
- Driving current +/- 10 mA
- Leak rate minimum (aiming at < 1liter/min)
- Integrated dose rate 10 kGy

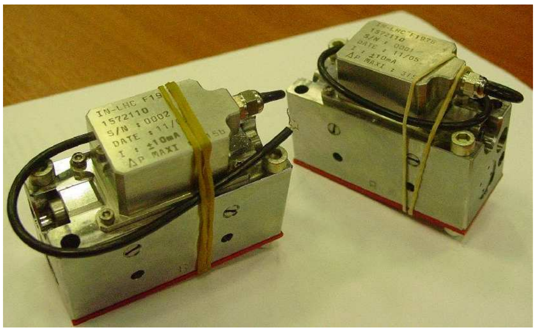

Figure 1: First two prototypes

TEST RESULTS WITH OIL

Initial settings from the manufacturer were carried out with oil. Pressure vs. current characterization curves for the two prototypes show differences in the behavior. Linearity error is usually close to 3 bars and for high pressure values (>190 bars) a saturation is observed.
The mean value of the hysteresis is close to 4 bars (2% of the full scale). Better adjustments of the two nozzles of the valves should provide better control of the spool position reduce the error and improve symmetry.
Internal leak rates of both valves are close to 0.95 liter per minute.

TEST RESULTS WITH WATER

Test rig description

The test rig is composed of a drilled block supporting the servovalve and all 4 pressure sensors.

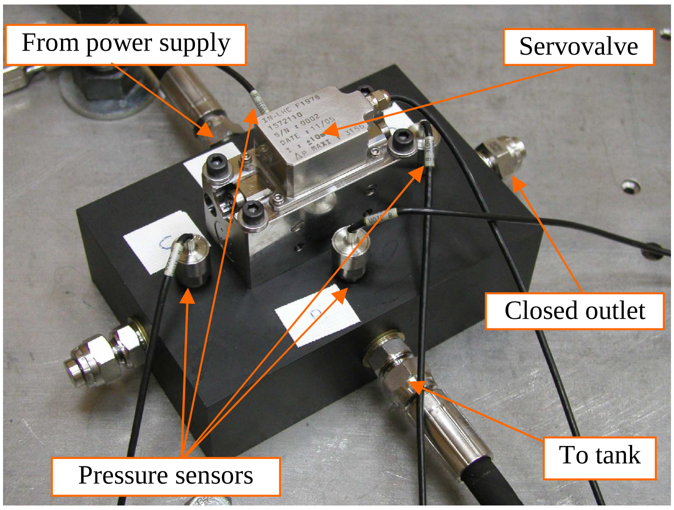

Figure 2: Test rig for water tests

Static response of the servovalves

Servovalve offset:
  Prototype #001 +6.5 bar
  Prototype #002 -11.6 bar
Maximal pressure difference:

  Prototype #001 +125 bars; -130 bars
  Prototype #002 +125 bars; -130 bars

Low-pass filtering of all pressures was made to reduce effect of noise on the pressure sensors.
Significant difference can be observed with the expected gain but these curves also clearly show that the same component with two distinct tuning parameters behaves differently.

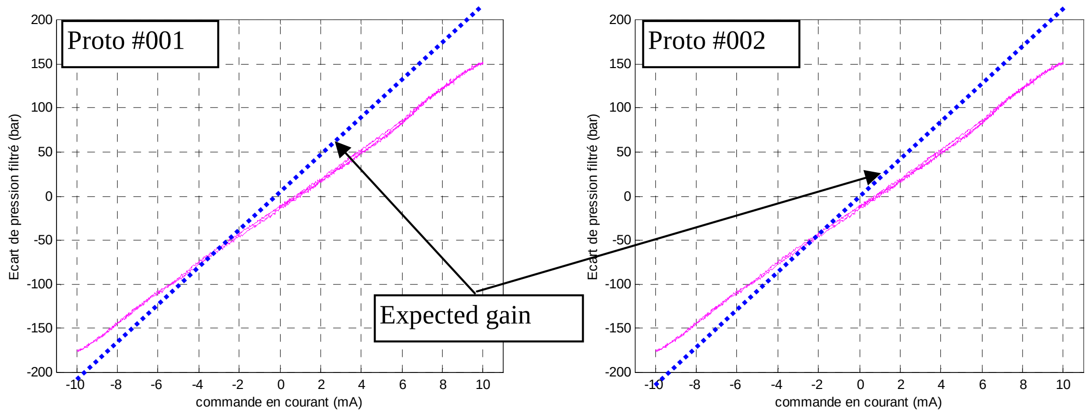

Figure 3: Static gain P=f(i) for proto #001 and 002. Current i in mA. Pressure P in bars.

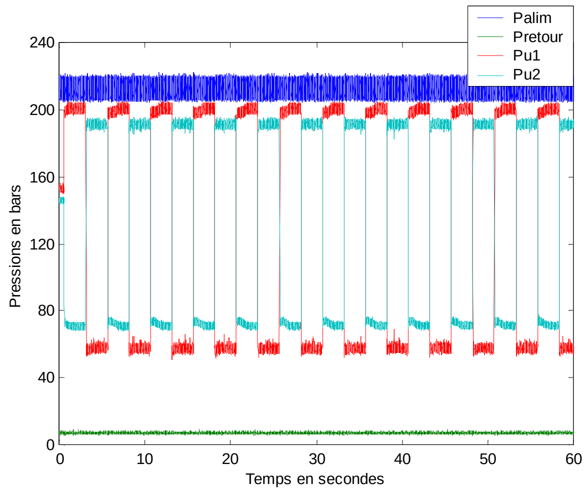

Figure 4: Time response to a 10mA periodic step signal

Further test carried out with periodic step signal (figure 4) show that the maximal pressure on the outlets is close to the supply pressure. It means that low gains of the servovalves are not due to internal leakage of the valve that could have been too high but are more likely due to bad settings adjustments. Improvements can therefore be expected in a next stage.

Dynamic response

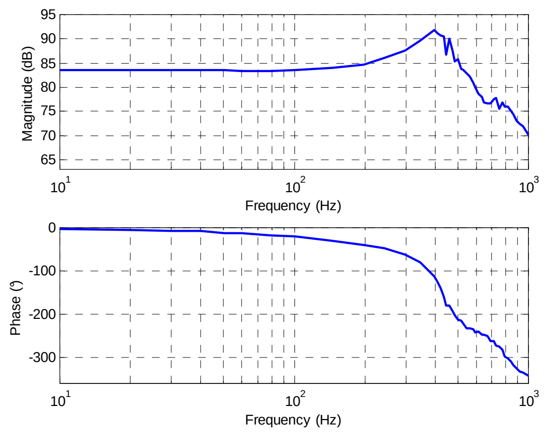

Figure 5: Gain and Phase response of the servovalve #002

Cut-off frequency at -3 dB is close to 450 Hz. This value is very high compared to the one expected according to numerical modelling which was 16 Hz.

Flow rates

On close ports both flow rates were below 1.2 liters per minute.
On open ports, flow rate higher than 20 liters per minutes were observed.

CONCLUSIONS

Pressure control water servovalve prototypes were tested with closed apertures for qualification and characterization with water. Factory settings were adjusted with oil. Linearity excepted, the performances of the valve with oil were close to those issued with numerical models in the design phase.
Although the maximal pressure difference between the two ports is lower than expected during water tests on both prototypes, the other requirements are better or close to the expected values. Taking into account that these tests are the first ones on the first prototype generation, these results are encouraging. Performances upgrade is expected with small modifications of the valve settings and change of an internal component. The gain of the valve will therefore raise and reach the required values. Unfortunately internal leak rate of the valve will probably become higher.
Further testing of the valve will focus on the definition of a model. Evaluation of its performances, both static and dynamic, will be carried out on operating conditions representative of those observed during real tests with robots.

REPORTS AND PUBLICATIONS

DTSI/SCRI/LPR/05RT080 Progress report

DTSI/SRI/LTC/06RT006 Characterization of water hydraulics pressure servovalve prototypes

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