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THE DESIGN OF A FLUIDIC COMPLEMENTARY GAIN CHANGER.(U)
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A fluidic complementary gain changer without moving parts has been designed and tested. Test results indicate that this gain changer has a pressure gain of about 20 and is capable of having 100-percent gain at the high-gain extreme and 0-percent gain at the low-gain extreme. This is a requirement for any gain changer.

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FIGURES

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1. INTRODUCTION

In many military control systems, a programmer-gain changer is needed. For example, in the fluidic backup flight control system for the V/STOL aircraft, a programmer-gain changer is needed to control the flight mode from hovering to conventional flight. Leonard et al[1] have evaluated 12 gain change concepts in their fluidic flight technology evaluation study. They concluded that the "carrot" valve-controlled, variable-input resistor approach and the nonlinear resistor gain change approach offer the least development risk. Each approach offers 100-percent gain at the high-gain extreme and 0-percent gain at the low-gain extreme. However, both approaches have a single push-pull output. As pointed out by Woods,[2] a complementary gain changing function is needed in many applications. As a result of this need, he designed a complementary gain changer by using a dual output chamber fluidic amplifier, as shown in figure 1. In this gain changer, the gain changing signal is provided by deflecting the partition laminate in the interaction region so that the output pressure developed in the upper and lower chambers depends on the position of the partition laminate. As a result, the pressure gains in the upper and lower outputs are complementary to each other. However, one significant disadvantage of this arrangement is that the pressure gain is low because the pressure recovery is only about half of that of the regular amplifier. To overcome this shortcoming and yet retain the complementary feature, a new fluidic complementary gain changer (FCGC) (fig.2) has been designed and tested.

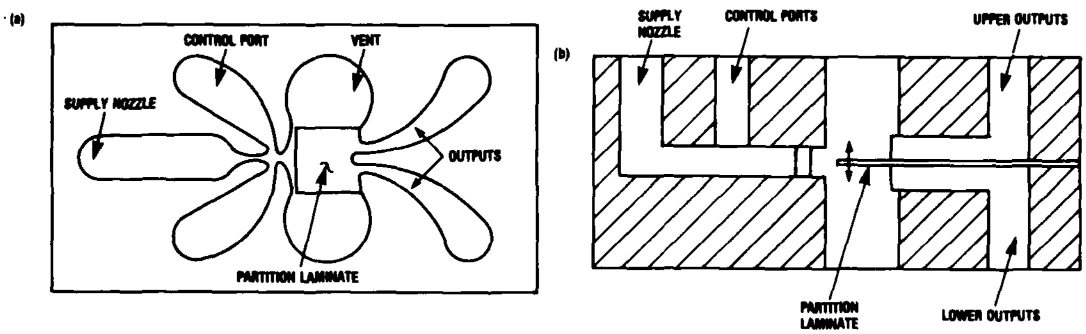

Figure 1. Dual output chamber complementary gain changer, schematic diagram: (a) top and (b) side.

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[1] *J. B. Leonard, T. A. Sorensen, and W. P. Stratford, Fluidic Flight Control Technology Evaluation: Problem Areas and Proposed Solution, Naval Air Systems Command MD-FC-07-79-02 (15 December 1979).*

[2] *R. L. Woods and Y.-T. Wang, A Flex-Chamber Fluidic Gain Changer, ASME 20th Anniversary of Fluidics Symposium, Chicago, IL (16 to 21 November 1980).*

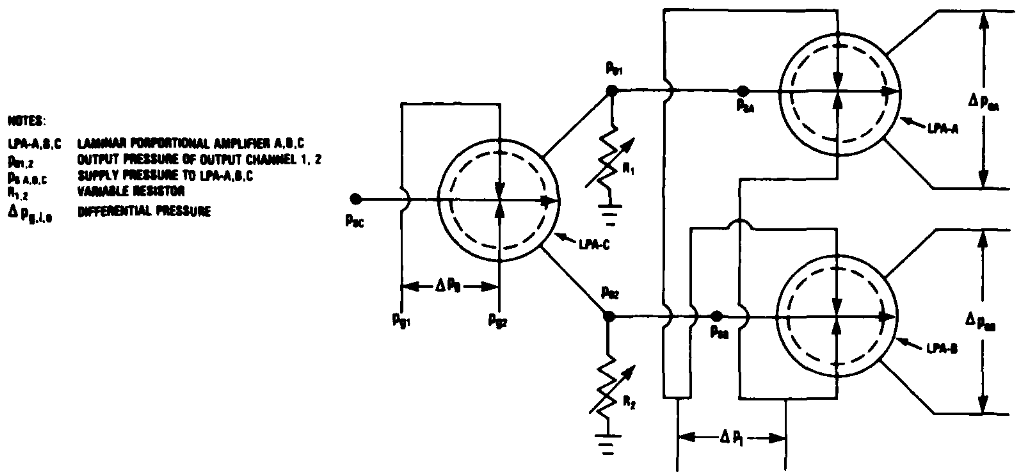

Figure 2. Fluidic complementary gain changer, schematic diagram.

2. DESCRIPTION OF DESIGN

The design concept of the FCGC is based on the fact that the pressure gain, G_p, of a laminar proportional amplifier, LPA, is proportional to the supply pressure, p_s. Therefore, by changing the supply pressure to the LPA, one can obtain the gain changing function. Figure 2 shows a schematic diagram of the FCGC. It consists of three LPA's and two variable resistors. These variable resistors can be connected either in parallel, as shown in the figure, or in series with LPA-A and LPA-B.

The following briefly describes the FCGC principles of operation. For a given supply pressure, p_{sC}, to LPA-C, the output pressures, p_{o1} and p_{o2}, become the supply pressures, p_{sA} and p_{sB}, to LPA-A and LPA-B, respectively. Ideally, when gain changing pressure

$$\Delta p_g = p_{g1} - p_{g2} = 0 ,$$

then

$$p_{sA} = p_{sB} .$$

However, it is difficult to make two LPA's with the same supply or output characteristics. Therefore, p_{sA} generally differs slightly from p_{sB}. However, p_{sA} can be made to equal p_{sB} by varying the variable resistors, R_1 and R_2, appropriately. When

$$p_{g1} > p_{g2} ,$$

then

$$p_{sB} > p_{sA} .$$

As a result, for a given input pressure, Δp_i,

$$\Delta p_{oB} > \Delta p_{oA}$$

and

$$G_{pB} > G_{pA} .$$

As Δp_g continues to increase, the difference in pressure gain increases. When Δp_g reaches a certain level, p_{sA} and G_{pA} become zero and G_{pB} is at its maximum value. When Δp_g is negative,

$$p_{sA} > p_{sB}$$

and

$$G_{pA} > G_{pB} .$$

Similarly, when Δp_g reaches a certain negative level, G_{pB} becomes zero and G_{pA} is at its maximum. As a result, the gains of LPA-A and LPA-B are complementary to each other. The desired pressure gain characteristic can be obtained by selecting the appropriate LPA design for both the driving LPA and the driven LPA's.

3. PRELIMINARY TEST RESULTS

A complementary gain changer has been designed and tested. In this gain changer, the driving LPA (LPA-C) is a standard Harry Diamond Laboratories (HDL) model 3.1108 LPA, which has a control nozzle width, b_c, equal to the supply nozzle width, b_s. The complete LPA-C is made up of three model 3.1108 LPA's in parallel, and the aspect ratio, σ, of each amplifier is 0.5. The driven LPA is an amplifier with $b_c = 4b_s$ and $\sigma = 0.75$. Figure 3 shows a schematic of these two LPA's.

Figure 4 shows a typical plot of supply pressures p_{sA} and p_{sB} of LPA-A and LPA-B as a function of the gain changing signal and supply pressure, p_{sC}, to LPA-C. The supply pressure of LPA-A and LPA-C can be driven to zero by the gain changing signal.

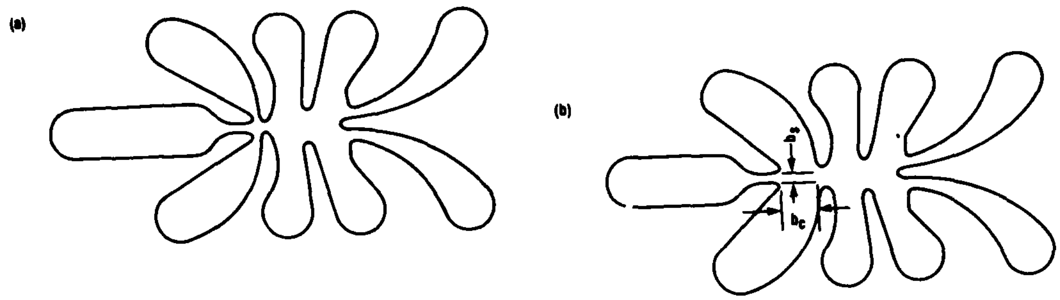

Figure 3. Model 3.1108 laminar proportional amplifiers, schematic diagrams: (a) LPA-C: control nozzle width (b_c) = supply nozzle width (b_s) and aspect ratio (σ) = 0.05; (b) LPA-A and LPA-B: b_c = $4b_s$ and σ = 0.75.

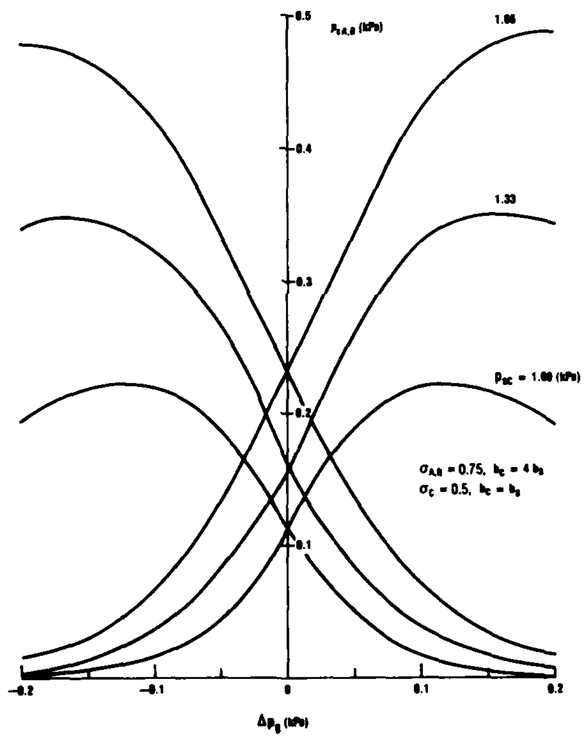

Figure 4. Supply pressure, $p_{sA,B}$, versus gain changing signal, Δp_g, at various supply pressures, p_{sC}, of LPA-C.

Figure 5 plots p_{sA} and p_{sB} as a function of p_{sC} with and without adjustment of R_1 and R_2 for $\Delta p_g = 0$. This figure shows that p_{sA} and p_{sB} can be set to equal each other with proper adjustment of R_1 and R_2. In this case, only R_1 needs to be adjusted.

Figure 6 shows a typical plot of the pressure gain of LPA-A and LPA-B as a function of the supply pressure. This LPA design has three times the block loaded pressure gain of that of the standard design model 3.1108 LPA because the control nozzle width of the LPA is greater than that of the model 3.1108 LPA. In general, the block loaded pressure gain is proportional to its control width. Therefore, it is advantageous to use LPA's with larger b_c's in designing a pressure gain block.

Figure 7 plots the pressure gain of LPA-A and LPA-B as a function of the gain changing signal at $p_{sC} = 1.33$ kPa. This figure shows that this gain changer has the capability of 100-percent gain for one LPA and 0-percent gain for the other LPA. This is a required capability for a complementary gain changer. The absolute value of the pressure gain can be changed by selecting the appropriate supply pressure to LPA-C. If more gain is needed, a second or third stage can be added to LPA-A and LPA-B to achieve the desired pressure gain for the system.

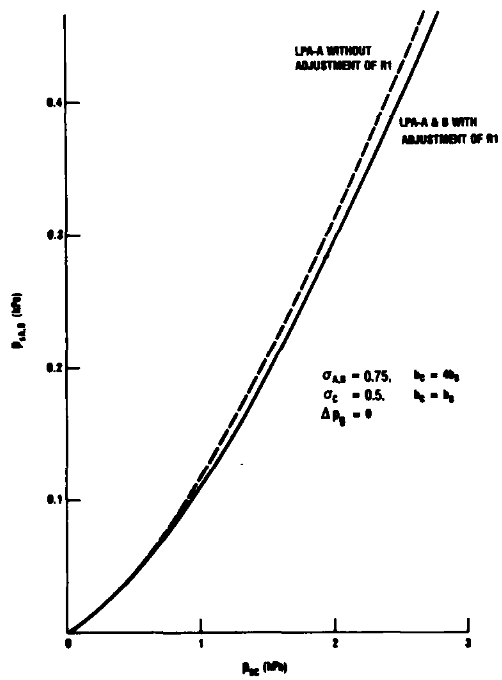

Figure 5. Supply pressure, $p_{sA,B}$, of laminar proportional amplifiers, LPA-A and LPA-B, as function of supply pressure, p_{sC}.

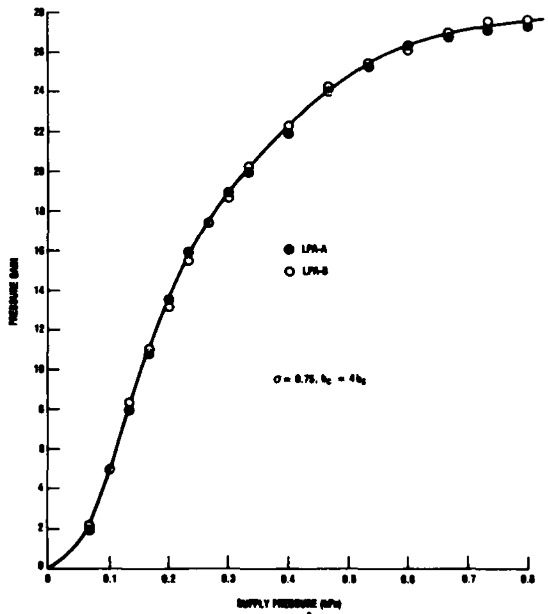

Figure 6. Typical gain characteristic of laminar proportional amplifiers, LPA-A and LPA-B.

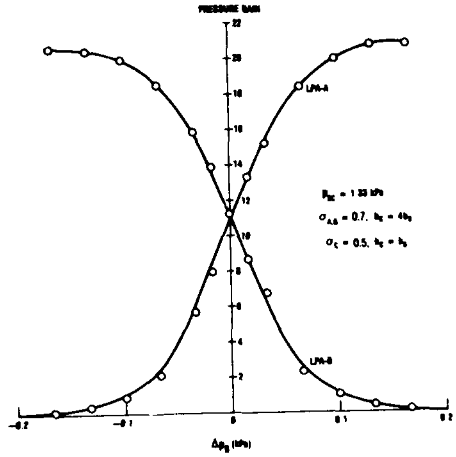

Figure 7. Pressure gain of laminar proportional amplifiers, LPA-A and LPA-B, versus gain changing signal, Δp_g.

4. SUMMARY

A fluidic complementary gain changer without moving parts has been designed and tested. Test results indicate that the supply pressure to the driven amplifiers, LPA-A and LPA-B, can be set to equal each other by adjusting the variable resistors, R_1 and R_2. The pressure gains of the driven amplifiers, LPA-A and LPA-B, are complementary to each other. The amplifiers can be driven by the gain changing signal to have a maximum pressure gain for one LPA and zero gain for the other LPA simultaneously. Test results indicate that this gain changer has a pressure gain of about 20 and can have 100-percent gain at the high-gain extreme and 0-percent gain at the low-gain extreme. This capability is required for any gain changer.

NOMENCLATURE

b_c	Control nozzle width (m)
b_s	Supply nozzle width (m)
G_p	Pressure gain
G_{pA}	Pressure gain of LPA-A
G_{pB}	Pressure gain of LPA-B
LPA	Laminar proportional amplifier
p_{g1}	Gain changing signal at control channel 1 of LPA-C (kPa)
p_{g2}	Gain changing signal at control channel 2 of LPA-C (kPa)
p_o	Output pressure (kPa)
p_{o1}	Output pressure of output channel 1 of LPA-C (kPa)
p_{o2}	Output pressure of output channel 2 of LPA-C (kPa)
p_s	Supply pressure to LPA (kPa)
p_{sA}	Supply pressure to LPA-A (kPa)
p_{sB}	Supply pressure to LPA-B (kPa)
p_{sC}	Supply pressure to LPA-C (kPa)
R_1, R_2	Variable resistors (kg/m^4-s)
Δp_g	Differential gain changing pressure (kPa)
Δp_i	Differential input pressure (kPa)
Δp_{oA}	Differential output pressure of LPA-A (kPa)
Δp_{oB}	Differential output pressure of LPA-B (kPa)
σ	Aspect ratio

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